trolled commercial fishery, rapacious sportsmen, and the results of short-sighted progress in the form of oil well drilling and spillage, and other side effects of our twentieth century style of progress. The overexploitation of the Frobisher Bay fishery in just 10 years of fishing should serve as a shameful lesson.

Nomenclature

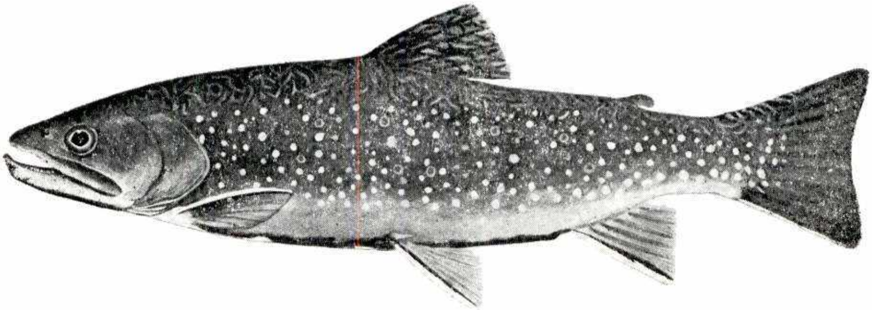
Salmo alpinus	— Linnaeus 1758: 309 (type locality Lapland, W. Gothland, etc.)
Salmo stagnalis	— Fabricius 1780: 175
Salmo rivalis	— Fabricius 1780: 176
Salmo Hearnii	— Richardson 1823: 806
Salmo Rossii	— Richardson 1835: LVI
Salmo alipes	— Richardson 1835: LVII
Salmo nitidus	— Richardson 1835: LVII
Salmo oquassa	— Girard 1854a: 262
Salmo arcturus	— Günther 1877a: 294
Salmo Naresi	— Günther 1877b: 476
Salvelinus alipes (Rich.) Gill & Jordan	— Bean 1879: 135
Salvelinus nitidus (Rich.) Gill & Jordan	— Bean 1879: 135
Salvelinus Hoodii (Rich.) Gill & Jordan	— Bean 1879: 135
Salvelinus arcturus (Günth.) Gill & Jordan	— Bean 1879: 135
Salvelinus Naresi (Günther)	— Bean 1879: 135
Salvelinus stagnalis (Fabricius)	— Dresel 1884: 255
	— Henn 1932: 1
Salvelinus aureolus	— Bean 1887: 628
Salmo marstoni	— Garman 1893: 23
Salvelinus alpinus (Linnaeus)	— Jordan and Evermann 1896–1900: 508
Salvelinus marstoni	— Vladykov 1954: 905
Salvelinus oquassa	— Vladykov 1954: 905

Etymology *Salvelinus* — an old name for char; *alpinus* — alpine.

Common names Arctic char, alpine char, Hearne's salmon, sea trout, Hudson Bay salmon, ivitaruk (in fresh water), ekaluk (eqaluk), European char, arctic salmon, arctic charr, trout, Copper-mine River salmon, blueback trout, Greenland charr, Quebec Red trout. French common name: *omble chevalier.*

BROOK TROUT

Salvelinus fontinalis (Mitchill)



Description Body typically troutlike, elongate, average length 10–12 inches (254–305 mm), only moderately laterally compressed, greatest depth at, or in front of, dorsal fin origin, but body depth variable, 20–28% of total length depending upon size, sex, and state of maturity. Head relatively large, 22–27% of total length, eye moderate, its diameter 15–22% of head length; snout somewhat rounded, its length greater than eye diameter, 25–33% of head length; mouth terminal, large, maxillary extending posteriorly to beyond posterior margin of eye, breeding males may develop a hook (or kype) at the front of the lower jaw; well-developed teeth on upper and lower jaws (premaxillary, maxillary, and dentary), on the head of the vomer (not on shaft), on palatines, on tongue (in 2 rows), basibranchial (hyoid) teeth usually lacking. Gill rakers 14–22 (4–7 on upper arch, 10–15 on lower) (*see* Vladykov 1954). Branchiostegal rays 9–13, usually fewer on right side (10–13 on left, 9–12 on right). Fins: dorsal adipose present; major dorsal rays 10–14; caudal with a shallow fork; major anal rays 9–13; pelvic rays 8–10, a distinct pelvic axillary process present; pectoral rays 11–14. Scales cycloid, small, in about 230 rows at lateral line, 110–130 pores along lateral line, lateral line straight. Pyloric caeca total range 23–55 but usually less than 50. Vertebrae 58–62.

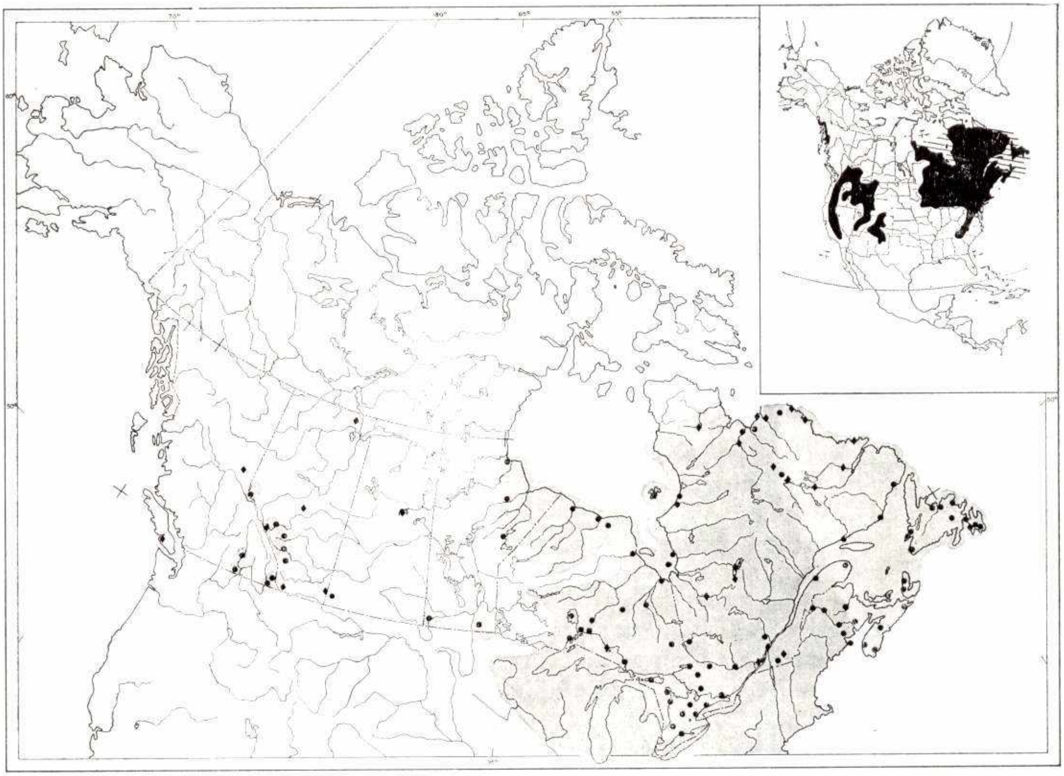
(*See also* Wilder 1952; Vladykov 1954; Bigelow 1963.)

Colour Back olive-green to dark brown, at times almost black, sides lighter, becoming silvery white below; light green or cream coloured wavy lines or vermiculations on top of head and on back, broken up into spots on sides. In addition to pale spots on sides are small discrete red spots surrounded with bluish halos. Dorsal fin with heavy, black, wavy lines, lending a marbled appearance. Caudal fin with variable black lines, sometimes two or three lines parallel to the trailing edge of the fin. Anal, pelvic, and pectoral fins with an immaculate white leading edge usually followed by black pigment and then reddish colouration. All colours intensified at spawning time, lower flanks and belly of males becoming orange-red with black pigmentation on either side of belly.

Sea-run brook trout become silvery with purple iridescence; only red spots are visible on sides. *See* colour illustration facing p. 218.

Systematic notes The brook trout exhibits considerable variation in growth rate, colour, and other features, throughout its range, but generally speaking it is a stable and well-defined species.

The systematic relationship between freshwater and anadromous (sea trout) populations was investigated by Wilder (1952), who also reviewed the nomenclatural history for the sea-run brook trout. Wilder concluded that sea-run brook trout were not taxonomically distinct from freshwater trout. Sea-run trout were long considered to be a species



distinct from the freshwater brook trout and were named *Salmo hudsonicus* by Suckley (1862b). Subsequently Hubbs (1926) designated the sea trout as a subspecies, *S. fontinalis hudsonicus*, but this view has not been substantiated. For additional information and discussion of freshwater and anadromous stocks, *see* Scott and Crossman (1964) and the many papers by Smith and Saunders, especially Smith and Saunders (1967).

Populations of non-speckled or non-spotted brook trout in a restricted portion of the Temiskaming District of Ontario were described by Henn and Rinkenbach (1925) as a distinct species, *Salvelinus timagamiensis*, the aurora trout. In a re-examination of this form, Sale (1967) demonstrated that it was closely allied to *S. fontinalis* and suggested that it be considered a subspecies, *S. f. timagamiensis*. Unfortunately the natural stock has been decimated and it is doubtful that any aurora trout live in any of the lakes from which it was described.

Vladykov (1954) and Slastenenko (1958) apparently favoured retention of *Baione* DeKay (1842) as a subgenus for *S. fontinalis* but this view does not have wide support.

Male brook trout may be crossed with female lake trout to produce a fertile hybrid, often called "splake." For additional information *see Systematic notes* for lake trout. Brook trout can also be crossed with brown trout to produce a so-called tiger trout; *see Systematic notes* for brown trout. An artificial hybrid between brook trout and kokanee (*Oncorhynchus nerka*) was described by Crossman and Buss (1966). *See also* Buss and Wright (1956, 1958) for additional information on hybrids involving brook trout.

Distribution The brook trout is a North American endemic species and under natural conditions occurs only in northeastern North America from the Atlantic seaboard south to Cape Cod, in the Appalachian Mountains southward to Georgia, west in the upper Mississippi and Great Lakes drainages to Minnesota, north to Hudson Bay.

In Canada, the brook trout is widely distributed throughout the Maritime Provinces, including offshore islands, Newfoundland, Labrador, and Quebec, west through the Great Lakes drainage of Ontario, north to James and Hudson bays including the Belcher and Akimiski islands, coastwise to northeastern Manitoba where it occurs in the Nelson and Hayes River systems and north along the Hudson Bay coast to Seal River. In Ontario, it is absent from Lake Attawapiskat and the immediate drainage system although it occurs in the lower reaches of the Attawapiskat River, and from the extreme western portion of the province (*see also* Ryder et al. 1964).

The brook trout has been introduced widely and often successfully into many parts of the world because of its appeal as a sport fish. Included in its extended range are many parts of western North America, South America (including the Falkland Islands), New Zealand, Asia, and many parts of Europe. *See* MacCrimmon and Campbell (1969) for a review of the world distribution of brook trout.

Biology The brook trout spawns in late summer or autumn, the date varying with latitude and temperature. Through southern and eastern Canada spawning occurs usually during late September, October, or November, but it may take place as early as late August in the north and as late as December in the southern part of its Ontario range (Ricker 1932).

Spawning takes place most often over gravel beds in the shallows of headwaters of streams but may be successfully accomplished in gravelly shallows of lakes if there is spring upwelling and a moderate current. In Lake Nipigon, large trout did not enter rivers but spawned on gravel beds near shore in water about 24 inches (61 cm) deep (Ricker 1932). Gravelly shallows of headwater streams with strong springwater flow are particularly favoured. Mature fish may travel many miles upstream to reach the spawning grounds. Males usually arrive first and often outnumber females. Individual males may display some territoriality but their aggressiveness increases when joined by a female. The actual spawning act is performed by one male and one female, but each may spawn with different mates during the reproductive period. The female clears away debris and silt from the nesting area by a series of rapid fanning movements of the caudal fin made while on her side. The circling and courting movements of the male, quite often larger than the female, produces currents which assist in cleaning the area. Both male and female will dart at intruders to drive them away. Spawning occurs during the daytime, in contrast to night spawning by lake trout.

Literature accounts of the spawning act differ, and accounts of the behaviour of hatchery fish, often artificially bred for generations, may not be characteristic of wild trout. In the Mad River, Ont., Ricker (1932) reported ". . . the females turn quickly on either side, give two to four flips of the tail, and the eggs are shot out." On the other hand, Greeley (1932) reported that the female took a position on the bottom of the nest, with pectoral and pelvic fins spread against the stones, at her side, the male arched his body to hold the female against the bottom and both vibrated intensely as eggs and milt were discharged. There are usually several extrusions followed by a resting period. The eggs are adhesive for a short period after extrusion which serves to prevent those not lodged in gravel from being washed away. On completion of spawning, the female covers the eggs with gravel in a manner resembling the excavation of the redd (*see* White 1930; Needham 1961).

The eggs are large, 3.5–5.0 mm in diameter. The number deposited depends upon the size of the female but may vary from 100 for a female 5.7 inches (144 mm) long to 5000 for one 22.2 inches (565 mm) in fork length. For further information on fecundity, *see* Vladykov (1956) who also provided coloured illustrations of dissected females to demonstrate prespawning and postspawning condition of ovaries.

The eggs incubate within the gravel substrate, the total time required depending upon such factors as temperature and oxygen tension. At 41° F (5° C) eggs hatch in about 100 days, at 43° F (6.1° C) in about 75 days, and at 50° F (10° C) in 50 days. The upper lethal temperature limit for developing eggs is about 53° F (11.7° C). When hatched, the larvae or sac fry remain in the gravel within the redd until the yolk is absorbed. They become free swimming when about 1.5 inches (38 mm) long. Scales begin to form when the young are about 2 inches (50 mm) long.

Brook trout can be aged by means of their scales. Scale samples are usually taken from above the lateral line, between the dorsal and the adipose fins.

The rate of growth varies greatly throughout the native range, depending upon local conditions. Brook trout may overpopulate small streams, resulting in a large number of small trout less than 10 inches (254 mm) long. Unlike lake trout or arctic char, the brook trout is relatively short-lived and wild trout seldom live longer than 5 years, and never beyond 8 years. In California, introduced trout are said to live to 15 years (McAfee 1966). Sexual maturity is usually attained at age 3, but some individuals may mature at age 2 (Cooper 1940; Baldwin 1948).

The maximum size for brook trout was a 14.5-pound (6.6-kg) specimen caught in Rabbit Rapids, Nipigon River, Ont., in 1915, by Dr J. W. Cook of Fort William. From time to time rumours of larger brook trout are circulated but none have proved to be true. Recently a report of a 19.5-pound trout caught in a lake north of Goose Bay, Lab., reached our notice. The specimen proved to be an arctic char, not a brook trout. A number of brook trout weighing 5–6 pounds are caught each year. The largest entered in the Ontario Federation of Anglers and Hunters Big Fish Contest during 1968–1970 weighed 7 pounds 5 ounces, but there were many in the 6-pound class. Fish over 10 pounds are rare and few have been reported in recent years. Comparative rates of growth for populations from across Canada follow:

		Age (*years*)							
		0+	1+	2+	3+	4+	5+	6+	7+
	SL								
sea-run	*inches*	–	–	7.9	9.7	10.8	13.2	15.6	–
Moser R., N.S.	*mm*	–	–	201	247	274	334	396	–
(Wilder 1944)									
	SL								
freshwater	*inches*	1.5	4.3	6.2	7.0	8.8	10.8	–	–
	mm	39	109	156	178	224	274	–	–
	FL								
Matamek L.	*inches*	1.5	3.5	4.9	6.8	8.4	9.9	11.6	13.3
Saguenay Co., Que.	*mm*	38	88	124	172	212	251	294	337
(Saunders and Power 1970)	Wt (*oz*)	–	0.3	0.8	2.1	3.9	6.6	10.9	–
	TL								
Red Rock L., Ont.	*inches*	1.4	6.1	9.1	11.7	14.8	17.4	–	–
(Baldwin 1948)	*mm*	36	155	231	297	376	442	–	–
	TL								
Nelson &	*inches*	–	–	11.6	15.2	17.3	19.1	20.9	–
Hayes R., Man.	*mm*	–	–	295	386	439	486	531	–
(& tributaries)	Wt (*oz*)	–	–	7.5	20.5	29.9	43.6	57.0	-
(Doan 1948)									
	FL								
Pyramid L., Alta.	*inches*	–	5.4	8.6	11.1	14.0	16.5	–	-
(Rawson and	*mm*	–	137	218	282	356	419	–	–
Elsey 1950)	Wt (*oz*)	–	1.5	5.5	10.5	22.0	34.0	–	–

The brook trout, or speckled trout as it is more frequently called in Canadian literature, has been widely used as an experimental animal and, hence, there is much information in the literature on many aspects of its biology not mentioned above (*see* Brown 1957a; Shepard 1955; Job 1955; under *Suggested Reading* section for pertinent literature).

Brook trout occur in clear, cool, well-oxygenated streams and lakes. They tend to seek temperatures below 68° F (20° C) when surface waters warm up. In Red Rock Lake, Algonquin Park, Ont., Baldwin (1948) observed that brook trout moved to depths between 15 and 27 feet (4.6–8.2 m) during July and August. In streams and rivers brook trout move downstream to larger bodies of water when temperatures rise and may move completely out of the river system into lake or sea. In the northern part of its range, the brook trout may remain in rivers throughout the summer, as in Ungava, Que. (Power 1966), or they may leave the streams and go to sea as they do in many Hudson Bay tributary streams in Ontario, Quebec, the Maritime Provinces (Smith and Saunders 1958, 1967) and Newfoundland (Scott and Crossman 1964).

Brook trout are carnivorous, and feed upon a wide range of organisms, although stomachs sometimes contain traces of plant remains. Young and medium-sized trout eat large numbers of aquatic insect larvae and terrestrial insects. In a very thorough study of brook trout in Ontario, Ricker (1932) provided also a review of the organisms eaten. The list of organisms is astonishing and suggests that brook trout will eat any living creature its mouth can accommodate: worms, leeches, crustaceans (cladocerans, amphipods, decapods), aquatic insects (over 80 genera eaten but mayfly, caddisfly, midge, and blackfly larvae common), terrestrial insects (over 30 families, ants sometimes in abundance), spiders, molluscs (including clams and snails), a number of fish species, including young brook trout and brook trout eggs, minnows, sticklebacks, and cottids, frogs, salamanders, and a snake (in a 7-inch trout). Although not mentioned by Ricker, larger trout, particularly in northern waters during summer, are known to eat numbers of small mammals, mainly the field mouse, *Microtus*, but also the redback vole, *Cleithrionomys*, and shrews. Sea-run trout eat invertebrates and fishes found in marine and brackish waters.

In a study of food consumption and growth, Baldwin (1957) observed that brook trout weekly ate 50% of their own weight (in minnows) at 55.4° F (13° C) but less than this amount at 48.2° F (9° C) and 62.6° F (17° C).

Brook trout engage in a limited amount of cannibalism, eating their own eggs at spawning time and their own young in spring (Ricker 1932; White 1924). White also noted that young trout were eaten by rock bass. Possibly the most serious predators are fish-eating birds, such as kingfishers and mergansers, whose brook trout eating habits have been documented by White (1936, 1937, 1938, 1953, 1957) for the Maritime region.

Long interest in brook trout as a hatchery-reared and pond-cultured sport fish has resulted in the accumulation of much information on its parasites.

Lyster (1940a) discussed parasitism of brook trout in Lake Commandant, Que. He reported three trematodes, one, *Ptychogonimus fontanus*, in considerable quantity in the stomach and upper digestive tract. Cestodes, especially the large tapeworm *Eubothrium salvelini*, light infections of the acanthocephalan *Neoechinorhynchus cylindratus*, and two species of nematodes were also reported. Lyster (1940b) also reported black-spot caused by the trematode *Apophallus brevis*.

Bangham and Hunter (1939) found light infections of the nematode *Cystidicloides harwoodi* only, in 40 of the 63 specimens they examined from the upper portions of streams flowing into Lake Erie.

MacLulich (1943b) studied parasitism of trout in Algonquin Park, Ont., and reported that microsporidian parasites, forming white cysts in the kidneys, were abundant in both lake and brook trout, the abundance differing with locality. He also reported small numbers of the trematode *Crepidostomum farionis* in the intestines of a few trout, and the unusual occurrence of two flukes, *Crepidostomum*, in the gall bladder of one trout from Red Rock Lake. Black-spot occurred on pectoral fins of some trout from Proulx and Red Rock lakes. The cestode *Diphyllobothrium* sp. was absent from brook trout he studied, but *Eubothrium salvelini* occurred in 66% of specimens examined and *Proteocephalus parallacticus*, a new species of tapeworm (MacLulich 1943a), and *P. ambloplitis* were also reported. Infestation by roundworms, *Cystidicola stigmatura*, was heavy but did not appear to seriously affect the hosts. *See* MacLulich (1943b) for detailed list.

Bangham and Venard (1946) reported several of the species of parasites reported by MacLulich, but added *Hepaticola bakeri* and *Contracaecum brachyurum*. In Lake Huron waters Bangham (1955) reported light infections only.

See Choquette (1948) for incidence of internal helminths in speckled trout in Laurentide Park, Que., and also Choquette (1955) for common occurrence of the nematode, *Metabronema salvelini*.

All nine specimens examined from Flynn Lakes, Gatineau County, Que., contained *E. salvelini* (Worley and Bangham 1952).

In British Columbia, where brook trout is an introduced species, Bangham and Adams (1954) reported it had fewer parasites than native forms, and stated that all parasites identified were of scattered occurrence, except *Crepidostomum farionis* (in 64% of the 110 specimens examined), *Metabronema salvelini* (22%), and *Bulbodacnitis globosa* (15%).

Mortalities of brook trout have been reported caused by acanthocephalans (Pippy and Sandeman 1967) and leeches (Rupp and Meyer 1954).

Ulcer disease and furunculosis may cause considerable loss of hatchery stock. *See* Snieszko (1952), McCraw (1952), Davis (1953), and Margolis (1954).

Relation to man The brook trout is a most highly esteemed game fish and one of the most popular game fishes in eastern Canada. It is fished by artificial fly, spin casting, or live bait. Since it is classed as a game fish, commercial sale for food is illegal in Ontario, but not everywhere in Canada.

Rearing brook trout in hatcheries has been practised for decades. In addition to government hatcheries, many private producers sell hatchery fish (fry, fingerlings, yearlings) for stocking private ponds. Many private trout clubs maintain their own brood stock, hatcheries, and rearing ponds, and offset some of their overhead by offering surplus stock for sale to other clubs.

For information on pond culture and practices, *see* Ayers et al. (1963), Cooper (1959), Eipper (1964), and Séguin (1955).

Nomenclature

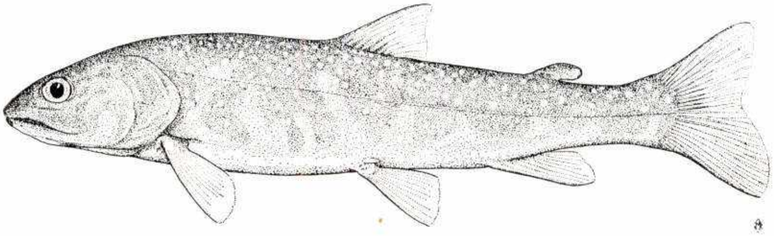
Salmo fontinalis	— Mitchill 1815a: 435 (type locality vicinity New York City, N.Y.)
Salmo canadensis	— Smith (*in* Cuvier 1834: 474)
Salmo immaculatus	— Storer 1857: 264
Salmo hudsonicus	— Suckley 1862b: 310
Salvelinus fontinalis	— Jordan and Copeland 1878: 430
Baione fontinalis	— Slastenenko 1958: 82
Salvelinus timagamiensis Henn and Rinkenbach	— Scott and Crossman 1967: 8

Etymology *Salvelinus* — an old name for char; *fontinalis* — living in springs.

Common names Brook trout, Eastern brook trout, speckled trout, aurora trout, brookie, square-tail, speckled char, sea trout, common brook trout, mud trout, coaster, eastern speckled trout, native trout, mountain trout, breac, squaretailed trout. French common names: *omble de fontaine*, *truite*, *truite de mer*, *truite mouchetée*.

DOLLY VARDEN

Salvelinus malma (Walbaum)



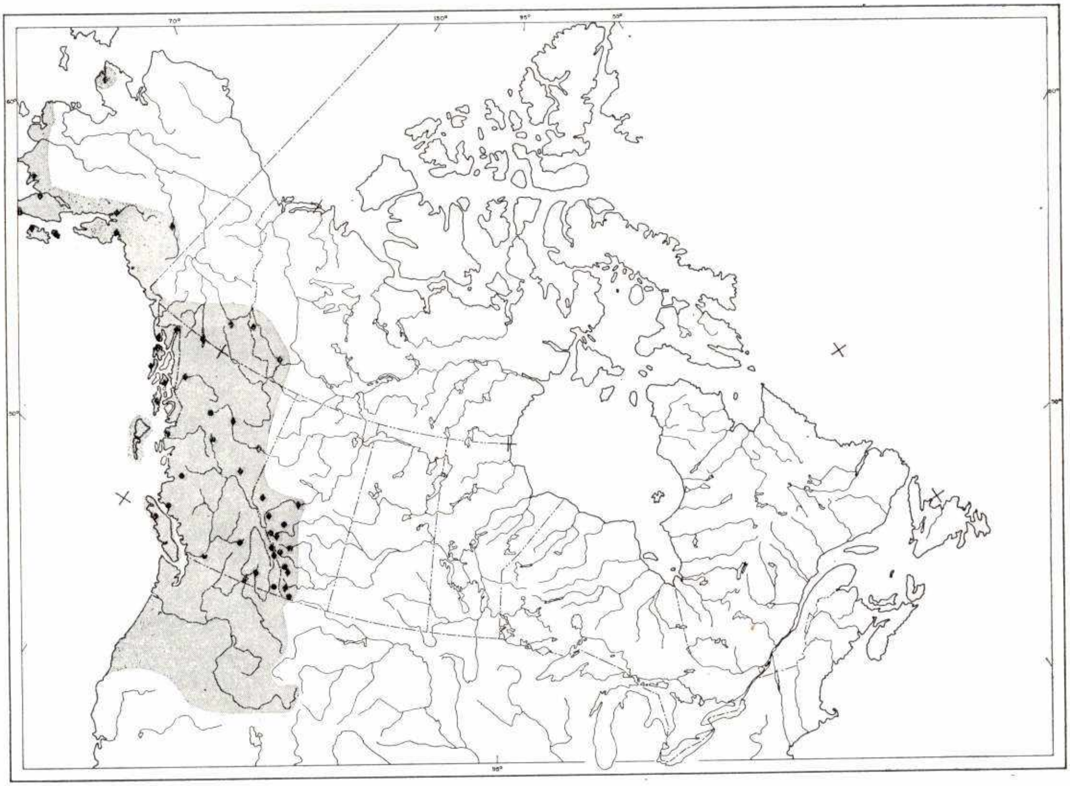
Description Body elongate, troutlike, average length variable, that of freshwater forms 12–18 inches (305–457 mm) and anadromous stocks 18–24 inches (457–610 mm), somewhat rounded, greatest body depth below dorsal fin about 20% of total length. Head rather long, about 15–28% of total length; eye large, 20–22% of head length; snout a blunt point, long, almost twice eye diameter; mouth terminal, large, maxillary to posterior edge of eye and often far beyond, kype well developed in breeding males of some anadromous populations; well-developed teeth on both jaws (premaxillary, maxillary and dentary, may extend almost to tip of maxillary), head of vomer (not on shaft), palatines (often joined to those on vomer), tongue (7–15), teeth on basibranchials variable with length, 0–44. Gill rakers moderate, 11–26, usually 3–9 on upper limb and 8–14 on lower limb. Branchiostegal rays 10–15 (10–15 + 11–15). Fins: slender, long dorsal adipose present; dorsal 1, at middle of body, not high nor long, 10–12 major rays (all rays 13–16); caudal broad, shallowly forked, tips rounded to pointed; major anal rays 9–11 (all rays 11–15); pelvics abdominal, not long, square, 9–11 rays; pectorals moderate, square, 14–16 rays. Scales cycloid, small, pored scales along lateral line 105–142; lateral line slightly decurved anteriorly, then straight, often with dip or arch posteriorly. Pyloric caeca 13–47 (19–47 in northern and southern populations, 13–18 in central Alaska). Vertebrae 57–70.

(*See also* Bajkov 1927; Dymond 1936; DeLacy and Morton 1943; and McPhail 1961, for proportional measurements and details of description.)

Colour Variable with size, locality, and habitat. Sea-run adults with back, upper head, and upper sides dark blue, the sides silvery, ventral surface silvery to white. In freshwater populations the back and upper sides are olive-green to brown, the sides a paler colour but bright red in spawning fish and at all times in some areas of Alaska, the underside white to dusky. The dorsal surface and sides are marked with yellow, orange, or red spots, more numerous and those along the lateral line smaller, than arctic char. The spots are usually smaller than the pupil of the eye; back occasionally with vermiculations. The paired fins and anal fin are white, or creamy on leading edge with a single thin black and thin red line behind. Dorsal and caudal fins dusky to brownish, sometimes with a few pale spots.

The young and some dwarf populations have 8–12 irregular, dark parr marks which are mere dark blotches in fish less than 3 inches (76 mm). There is fine dark speckling on the lower sides, and the dorsal and adipose fins are dusky but without spots.

Spawning males, especially of anadromous populations, turn red on the ventral surface and tip of snout. The lower jaw, operculum, and parts of the head are black, the back and sides turn olive-brown. The spots become a more vivid orange-red, the pectoral, pelvic, and anal fins red-black with a white leading edge, the snout thickens and the lower jaw turns up. Females change less.



Systematic notes The Dolly Varden was originally described by Walbaum as a distinct species, *Salmo malma*. There are a number of early synonyms (*see* La Rivers 1962; Morton 1970). In 1909 Berg suggested that it was not distinct from the arctic char, and gave it subspecies status calling it *Salvelinus alpinus malma*. It was variously known as a species and subspecies over the years. Jordan et al. (1930) considered it distinct and mentioned two subspecies, *S. m. malma* and *S. m. spectabilis*. At least until recently, Russian workers recognized two subspecies in Asia, *S. m. malma* and *S. m. krascheninnikovi*. McPhail (1961) said there were two distinct forms in North America, north of the Alaska Peninsula (65–71 vertebrae, 11–41 lower limb gill rakers), and south of the Alaska Peninsula (57–67 vertebrae, 8–12 lower limb gill rakers). He did not give them names, and Morton (1970) was convinced all subspecific names for *S. malma* in North America should be suppressed.

The documentation of the species status of the Dolly Varden, at least in North America, was given in detail by DeLacy and Morton (1943), and McPhail (1961). *Salvelinus parkei*, a form commonly placed in the synonymy of this species, is considered by some distinct.

The common name of this fish is probably the only one made up of the Christian name and surname of a fictitious, literary character. It is, therefore, the only one in North America regularly spelled with capital letters. Dolly Varden was a gaily dressed, young woman in Dickens' novel "Barnaby Rudge." During a visit by Dickens to North America a pink-spotted calico material became very popular and was called Dolly Varden. A woman is supposed to have seen *S. malma* during this period and referred to it as a Dolly Varden trout (Dymond 1932c).

Distribution This species is found in the fresh and salt water of western North America and eastern Asia. It occurs from the

McCloud River in northern California, western Montana, and isolated streams in Nevada and Idaho (nonmigratory populations), north to Seward Peninsula, Alaska. On the Asian side it occurs from the Anadyr River, USSR, south to the Yalu River, Korea.

In Canada it occurs from the headwaters of the South Saskatchewan River in Alberta, northwest through all but extreme northeastern British Columbia and the Okanagan River system, on Vancouver and Queen Charlotte islands, and in the headwaters of the Yukon, Liard, Nahani, Peace, and Athabasca rivers. Dolly Varden are common in central Yukon Territory and present in the extreme southwestern part of the Northwest Territories. Records from other Mackenzie River tributaries, and from the arctic coast, may actually be arctic char.

There are anadromous and nonanadromous populations from Washington north but the California, Nevada, Montana, and Idaho populations are freshwater only. The anadromous fish apparently do not move out into the open ocean but remain close to shore near the river mouths.

Biology Most of the detailed work on the biology of this species has been carried out in Alaska. Works by Armstrong (1965), Heiser (1966), Blackett (1968), and an annotated bibliography by Armstrong and Morton (1969) provide most of the information.

Like other chars, the Dolly Varden is a fall spawner. It spawns in different areas from September to early November (usually October). Anadromous fish migrate from the sea and enter river mouths from May to December (usually August to September). There is a strong homing tendency. Spawning populations of large lakes move into inlet rivers at about the same time. Secondary sexual characteristics do not develop until anadromous fish have been in fresh water for some time. Spawning takes place during the day, and to a lesser extent at night, in rivers of moderate current with a bottom of medium to large gravel, and at water temperatures near 46° F (7.8° C).

On the spawning grounds males are aggressive, charge, nip, and drive other males away from the redd. The redd is dug by the female usually with the up-and-down action of tail but in some non-anadromous populations observers have suggested that it is with a side-to-side motion. This unusual action may be part of post-spawning behaviour. Redds are usually 12–24 inches (305–610 mm) in diameter, at times as much as 12 inches (305 mm) deep, and usually at least 20 feet (6.1 m) apart. A female is often attended by as many as four or five males, but a larger one is usually dominant. There is prespawning courtship of body pressing and quivering. Sex products are released when the female and one or more males swim into the nest, press closely together, arch their backs, vibrate and the mouths gape. (*See also* Needham and Vaughan 1952.)

Egg number in females may be as high as 8000 in Montana, but differs by area and for anadromous and non-anadromous stocks. Averages were between 1337 and 8845 in Montana and 1336–3387 in Alaska. The mature eggs are usually 4.5–5.5 mm in diameter, orange-red, and demersal. After spawning the female covers the nest by digging at the upstream end and displacing gravel into it. The adults are in poor condition after spawning and move down to the lake to spend the winter there.

Early development of the eggs and young was given in detail by Blackett (1968). Most hatching occurs in the spring, March to April, or about $4\frac{1}{2}$ months after spawning. The alevins are about 18.2–19.4 mm at hatching. They usually spend about 18 days in the gravel, emerging in late April to mid-May when the yolk is nearly used up, when they are about 20–25 mm in length. They are very inactive at first and remain quiet on the bottom but soon commence active feeding. Growth is rapid at first, slowing in later years. Young-of-the-year in Alaska are 1.2–1.8 inches (32–47 mm) long in October and juveniles found in streams are usually 1.0–5.9 inches (20–150 mm) in length. The following table gives the age–length relation for four localities.

The table indicates a decrease in growth rate toward the north. The 1927 figures for

		Age (*years*)											
	FL	0	1	2	3	4	5	6	7	8	9	10	11
Eva Creek, Alaska (anadromous) Heiser (1966)	*inches*	0.8–1.7	2.0–2.9	2.4–4.0	3.4–4.1	8.1	9.8	12.4	14.6	15.5	18.7	17.0	17.1
	mm	21–44	50–74	61–100	86–106	206	249	315	372	394	476	433	435
	Wt (*lb*)	–	–	0.02	0.06	0.16	0.28	0.57	0.90	1.06	1.88	1.46	1.05
Bow R., Alta.	*inches*	–	6.5	8.3	9.7	10.6	12.6	13.2	–	–	15.9	–	–
Miller (1949)	*mm*	–	165	211	246	269	320	335	–	–	404	–	–
	Wt (*oz*)	–	2.0	3.5	5.6	7.6	12.0	13.0	–	–	24.0	–	–
Jasper National Park, Alta.	*inches*	2.3–2.9	–	7.8–9.0	9.8–11.8	13.0–15.7	16.2–18.1	19.7–21.2	22.0–24.4		–	–	–
Bajkov (1927)	*mm*	60–75	–	200–230	250–300	330–400	410–460	500–540	560–620		–	–	–
Upper Campbell L., Vancouver Island, B.C.	*inches*	–	9.1	9.4	11.4	–	–	–	–	–	–	–	–
McMynn and	*mm*	–	231	239	290	–	–	–	–	–	–	–	–
Larkin (1953)	Wt (*oz*)	–	4.2	5.0	9.5	–	–	–	–	–	–	–	–

Jasper National Park were, in the original, given at half year intervals, and other than year 0 have been set back here. Unless the growth rate in that Jasper Park lake was phenomenal this alignment seems more logical. The Eva Creek, Alaska, population is anadromous and goes to sea after 3 or 4 years in fresh water. The increase in length between years 3 and 4 as a result of this is about 4 inches (102 mm), and they almost double their weight. In non-anadromous populations the young may spend from several months to 3–4 years in streams, moving then to a lake, just as the anadromous stocks move to sea.

Sexual maturity is reached in years 3–6 in both types of populations. Males often mature a year earlier than females. In the northern part of the range not all adults migrate or spawn every year. At least some fish spawn every year from year 6 to year 10 or 11. Maximum size varies with location and between anadromous and non-anadromous stocks. Dolly Varden apparently grow to 50 inches (127 cm) length and 32 pounds weight according to McPhail and Lindsey (1970) but some anadromous populations reach only 5½ pounds, and maximum weight in Alberta has been given as 14 pounds 13 ounces. Inland, high-altitude and northern populations are often stunted and do not exceed 12 inches (305 mm) in length. The angler record is given by *Field and Stream* magazine as 40½ inches (102.9 cm) length, 29¾ inches (755 mm) girth, and 32 pounds weight. This fish was caught in Lake Pend Oreille, Idaho, in 1949. It may be the fish referred to by Paetz and Nelson as 50½ inches (128.3 cm) and McPhail and Lindsey as 50 inches (127 cm). Several just over 28 pounds have been taken by sportsmen in Kootenay Lake, B.C.

Ages to 20 years in California have been given (Carlander 1953) but 10–12 years would seem to be more usual over the whole range.

Habitat of the young for 3–4 years is the gravelly spawning stream in which they were spawned. They apparently move about over the length of these streams. The adults are found in cold lakes, gravelly to rather muddy (Peace River area) rivers, and in the sea. Anadromous stocks migrate seaward out of the lakes or rivers in late May to early June. They spend anywhere from 60 to 160 days in the sea, moving only short distances from the river mouth or staying in tidal water. They move back into the rivers from May to December, but usually in mid-July to September.

Summer food of stream-resident young is apparently made up largely of adult and immature insects, snails, and leeches. Salmon eggs and insects are important in the fall. The Dolly Varden has long enjoyed the reputation of a serious, or the most serious, predator on young salmon and a bounty was long paid on Dolly Varden in Alaska. This predaceous habit has led to at least 47 published studies of its food (*see* Pritchard

1936; Roos 1959; Lagler and Wright 1962; Narver and Dahlberg 1965) and overall, the Dolly Varden does not seem any worse than cutthroat trout, coho salmon smolts, or sculpins. In certain areas and especially at time of downstream migration of young salmon it consumes large numbers of salmon even when 5–6 inches (127–152 mm) in length. In May and June at Cultus Lake, individuals often have eaten as many as 90 sockeye salmon each. In the sea, young salmon are about fourth in importance as food, capelin and sand lance constituting 85% of the food volume. In general, food of Dolly Varden at Chignik, Alaska, consisted, in order of percentage occurrence in fish which contained food, of caddisfly larvae, dipterous larvae, sockeye fingerlings, dipterous adults, isopods, fish remains, caddisfly pupae, sculpins, and salmon eggs. Various other fishes such as sand lance, smelt, blackfish, sticklebacks, and a variety of invertebrates such as stoneflies, beetles, amphipods, ostracods, spiders, gastropods, earthworms were also present. In estuaries, whitespotted greenling, silverspotted sculpin, euphausiids, salmon offal, polychaete worms, and herring have been reported. In the interior of British Columbia they eat peamouth, kokanee, and mountain whitefish. Withler (1948) reported that in some years they ate significant numbers of red-backed mice in the Skeena River, Ricker (1933) reported them gorging on the remains of dead Pacific salmon, and Dymond (1932c) included moles, frogs, and birds.

The larger young and the adults are obviously competitors with other salmonids for food. Fall spawning adults compete with Pacific salmon but not trout for spawning grounds. Little is known of fishes which prey on the Dolly Varden.

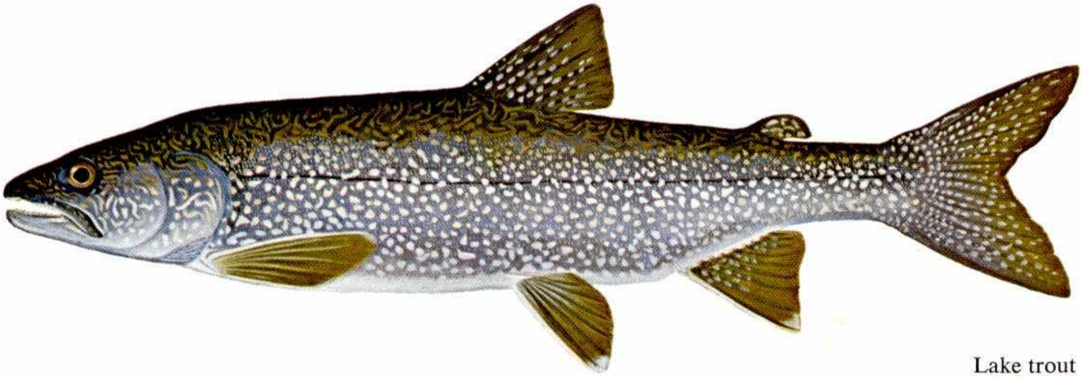
Bangham and Adams (1954) found all 51 specimens of this species which they examined from nine locations in British Columbia contained parasites. They reported that the trematode *Crepidostomum farionis* and acanthocephalan *Neoechinorhynchus rutili* were present in 69% of the Dolly Varden from all but two locations. The cestode *Eubothrium salvelini* occurred in 20% of the Dolly Varden and, with one exception, in all locations sampled. *See* Bangham and Adams (1954) for other marine and freshwater parasites identified. Margolis (1967b) studied a collection of this species from the Kitimat River, B.C., and identified the nematode *Salvelinema salminicola* in the swim bladder. Reed (1967) reported Dolly Varden infected with black-spot, the copepod *Salmincola* sp.; the nematode *Eustrongylides* sp.; and the roundworm *Philonema* sp. from Old Tom Creek, southeastern Alaska. Furunculosis has apparently caused serious losses in Dolly Varden populations.

Hoffman (1967) listed the following parasites for this species in North American fresh waters: trematodes (8), cestodes (7), nematodes (7), acanthocephalans (4), crustaceans (5). He also listed parasites from Russia.

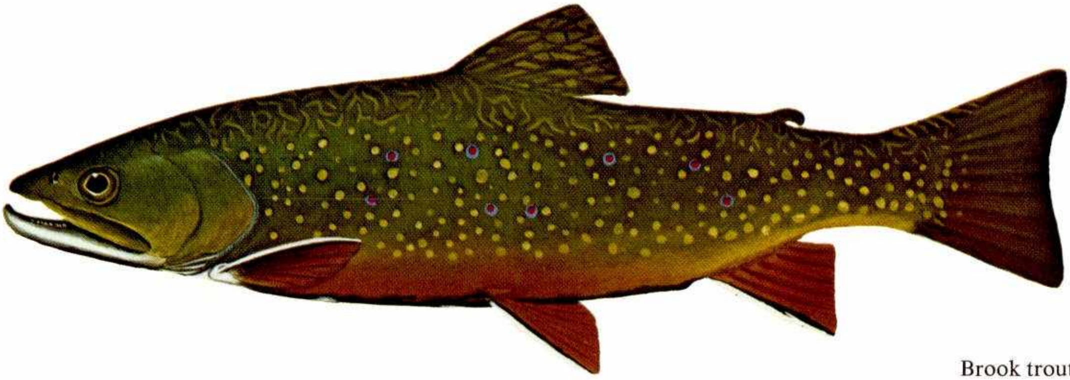
Dolly Varden may hybridize with brook trout in Alberta.

Relation to man The most important relation to man of the Dolly Varden was long considered to be its extensive destruction of salmon and trout which were more valued than it was. As a result of this reputation in Alaska, a bounty of 2½ cents each was paid, and they were destroyed by the thousands when taken in traps and weirs. Up to 20,000 dollars a year were spent on bounties in the 1930's. This charge may have been overdone according to McPhail and Lindsey (1970). However, according to Foerster and Ricker (1942), reducing the number of Dolly Varden and squawfish in Cultus Lake, B.C., was calculated to have "saved" 3.8 million migrant sockeye salmon which, according to their calculations, would yield an additional return of 38,000 adult sockeye. The controversy is probably not ended.

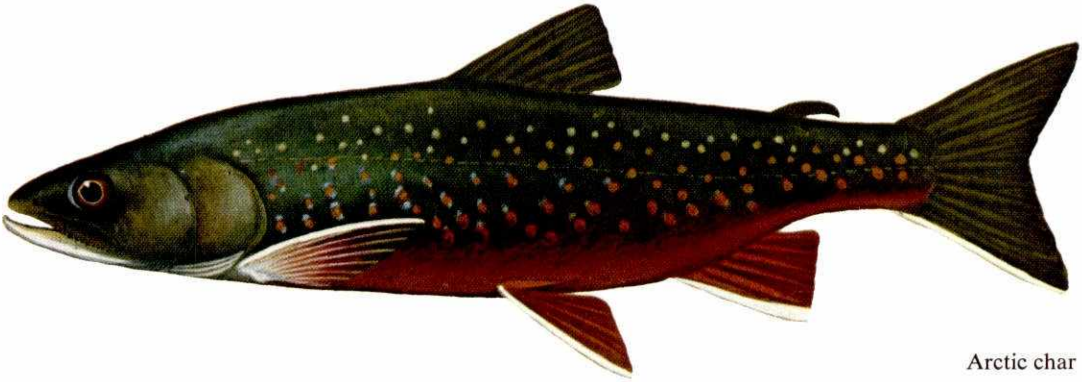
As a sport fish, the Dolly Varden will take most artificial lures and smaller ones can be taken by fly fishing. Although they can constitute a quarry of large size, they do not have the sporting qualities of other trouts and, although popular in eastern B.C., are not looked upon with much favour by anglers, except where other trout are not abundant. It is somewhat more popular in Montana, Idaho, and Alaska. They were at one



Lake trout



Brook trout



Arctic char

time taken incidental to catches of other fishes in Alaska, processed as fresh, fresh-frozen, canned, or dried fish, and sold commercially. In Kootenay Lake B.C., up to 1930, a few Dolly Varden were caught for sale to hotels in Nelson, B.C. Since 1950 the sportsmen's catch of this species has steadily increased.

Nomenclature

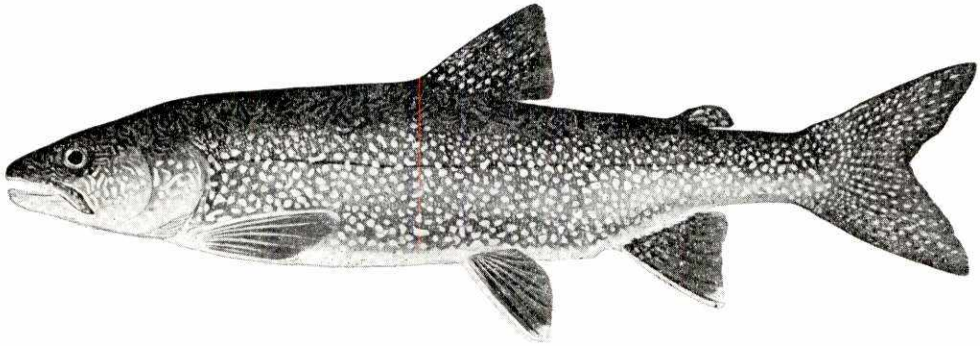
Salmo Malma	— Walbaum 1792: 66 (type locality rivers of Kamchatka Peninsula, Siberia)
Salmo spectabilis	— Girard 1857b: 218
Salmo bairdii Suckley	— Suckley 1862b: 309
Salmo parkei Suckley	— Suckley 1862b: 310
Salmo Campbelli, nob.	— Suckley 1862b: 313
Salmo parkii	— Günther 1866: 121
Salmo lordii	— Günther 1866: 148
Fario Lordii	— Lord 1867:
Salmo tudes	— Cope 1873: 24
Salvelinus spectabilis	— Jordan 1878c: 79
Salvelinus bairdii	— Jordan 1878c: 82
Salvelinus malma	— Bendire 1882: 86
Salvelinus namaycush	— Eigenmann 1895: 115
Salvelinus parkei	— Jordan and Evermann 1908: 210
Salvelinus alpinus malma (Walbaum)	— Bajkov 1927: 383
Salvelinus malma spectabilis (Girard)	— Jordan, Evermann, and Clark 1930: 61
Salvelinus malma (Walbaum)	— Dymond 1932c: 37
Salvelinus malma tudes	— Morton 1970: 585

Etymology *Salvelinus* — an old name for char; *malma* — the common name of this species in Kamchatka.

Common names Dolly Varden, Dolly Varden char or charr, trout, bull trout, red-spotted Rocky Mountain trout, red spotted trout or char, Pacific or western brook char or brook trout, sea trout or char, salmon-trout. French common name: *Dolly Varden*.

LAKE TROUT

Salvelinus namaycush (Walbaum)



Description Body typically troutlike, elongate, total length usually 15–20 inches (381–508 mm), somewhat rounded, greatest body depth under, or in front of, dorsal fin origin, 18–26% of total length, variable, dependent upon age, sex, and state of maturity. Head stout, broad dorsally, its length about 21–28% of total length; eye relatively small in adults, 12–20% of head length; snout long, its length greater than eye diameter, 26–36% of head length; mouth large, terminal, snout usually protruding slightly beyond lower jaw when mouth closed, maxillary extending beyond posterior margin of eye on specimens 8 inches (203 mm) or longer; premaxillaries forming tip of snout sometimes enlarged and almost beaklike on large fish; teeth developed on upper and lower jaws (premaxillary, maxillary, and dentary), on head of vomer only (not on shaft), palatines, tongue (in 2 rows), and on basibranchial (hyoid). Gill rakers, total range 16–26 (*See* Martin and Sandercock 1967). Branchiostegal rays total range 10–14 (11–14 + 10–13), usually fewer on right side. Fins: dorsal adipose present; dorsal 1, major rays 8–10; caudal distinctly and deeply forked; major anal rays 8–10; pelvic rays 8–11, pelvic axillary process present but small; pectoral rays 12–17. Scales cycloid, small, pores along lateral line 116–138, lateral line slightly decurved anteriorly, then straight. Pyloric caeca 93–208, the number apparently increases with increase in size but 85% of counts fall within range of 120–180 caeca. Vertebrae 61–69.

Nuptial tubercles minute, present on scales around anal opening of males and females (Vladykov 1954).

See also Vladykov (1954), Qadri (1967), McPhail and Lindsey (1970).

Colour Overall colouration light spots on a darker background and light below. The whole body, including head, dorsal, adipose, and caudal fins, covered with innumerable light-coloured spots on a background colour that varies from light green or gray, to dark green, brown, or almost black. The background colour varies greatly, and trout in large lakes are sometimes so silvery that the spots are difficult to see. The spotting usually more intense on small fish, (under 5 pounds). Red spots are absent on lake trout but orange or orange-red colouration may be evident on pectoral, pelvic, especially anal, and sometimes caudal fins. Such fin colouration is more apparent on populations in northern Canada. Narrow white border sometimes present on anterior margin of pectoral, pelvic, and anal fins but never as wide or immaculate as on *Salvelinus fontinalis*. Young lake trout have distinctive parr marks, about 7–12 in number, but most variable and frequently interrupted; the parr marks are narrow, the interspaces being equal to, or greater than, the width of the parr marks. *See* colour illustration facing p. 218.

Systematic notes The description of the lake trout is usually credited to Walbaum (1792), based on a description of a specimen from the Hudson Bay area which he called *Salmo namaycush*. However, the nomenclatural history is under review by N. V. Martin and further discussion must await the results of his studies.

Although the specific distinctness of the lake trout from other chars is generally accepted, the generic placement has been often in the literature and some authors (particularly Vladykov 1954, 1959, and his former students) preferred to employ *Cristivomer* as the generic name. For further information on this question *see* Kendall (1919), Morton and Miller (1954), Vladykov (1963), and Lindsey (1964). We prefer to place the lake trout with the other chars in the genus *Salvelinus,* in agreement with McPhail and Lindsey (1970).

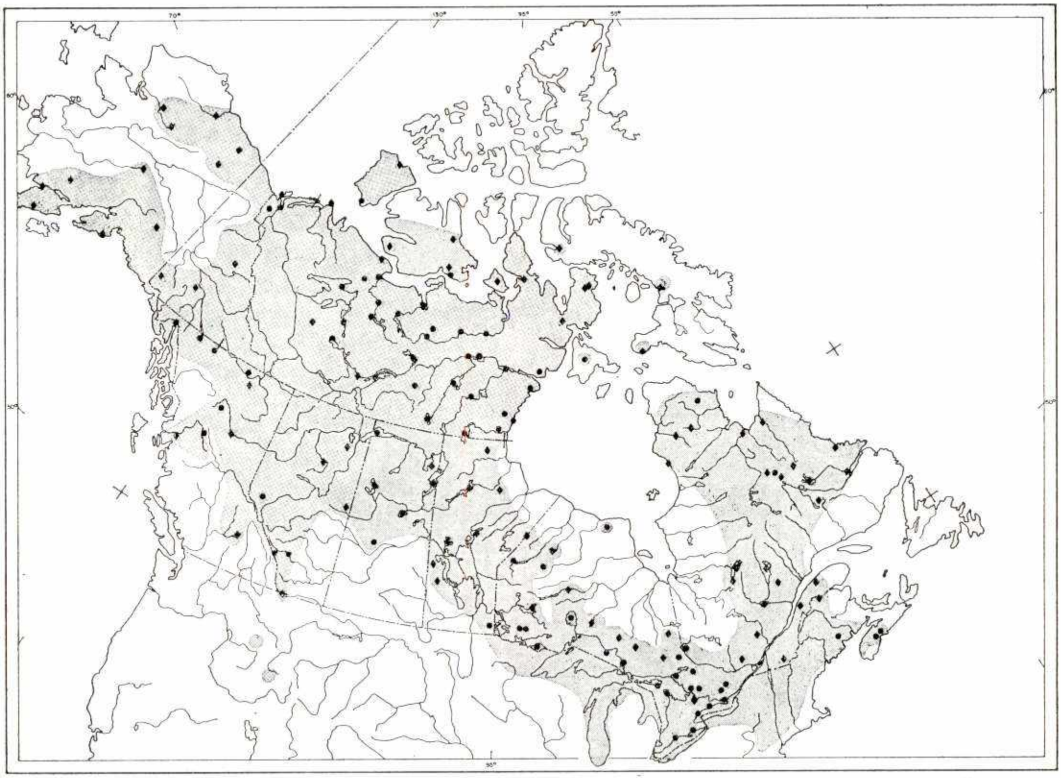
A form of the lake trout found in the deep waters of Lake Superior is called a siscowet and is sometimes regarded as a subspecies, i.e., *Salvelinus namaycush siscowet* (Agassiz). The siscowet is exceedingly fat and was said to spawn at depths over 300 feet (91.4 m). However, all forms of intergrades occur between typical lake trout and siscowets in Lake Superior, which had a number of apparently distinct subpopulations of trout. For further information *see* Eddy and Surber (1960), Eschmeyer and Phillips (1965), Rahrer (1965), Kahn and Qadri (1970).

The lake trout has been hybridized quite successfully with the brook trout to produce a fertile hybrid called a "wendigo" or "splake" (from *sp*eckled and *lake* trout). This hybrid is produced by fertilizing lake trout eggs with brook trout sperm. Splake have been planted in many parts of North America but particularly in Ontario, where a selective breeding program is conducted. The hybrid has been introduced into the Great Lakes where individuals have been recaptured 5 and 6 years after planting, some weighing up to 16 pounds. They grow more quickly than either parent, have an omnivorous diet which includes plankton and aquatic insects and so resembles the brook trout, and are known to live for at least 9 years. Splake reach maturity in about 3 years. They tend to spawn during both night and day, although lake trout spawn at night and brook trout during the day. They are intermediate in appearance and characters between the two parents, but usually lack the deeply forked tail or caudal fin of the lake trout. They can be positively identified by the number of pyloric caeca which is intermediate: brook trout 23–55; lake trout 93–208; splake 65–85. Christie (1960) gave a vertebral range for the hybrid of 56–66. For further information *see* Stenton (1950, 1952), Scott (1956), Budd (1957a, 1959), Christie (1960), Martin and Baldwin (1960), Tait (1970).

Distribution The lake trout is of natural occurrence and widely distributed only in northern North America, but it has been introduced elsewhere. Its natural North American range coincides most closely with the limits of Pleistocene glaciation (Lindsey 1964). Even within the general range, its distribution pattern exhibits peculiar clustering in certain regions and complete absence from others that appear equally suitable. Details of its biology and distribution are under critical study by N. V. Martin.

In the United States, the lake trout occurs in the New England states, the Great Lakes states of New York, Pennsylvania, Michigan, Wisconsin, and Minnesota, the western states of Montana, Idaho, and Alaska.

In Canada, the lake trout occurs in southwestern Nova Scotia, New Brunswick, north throughout Quebec and many parts of Labrador, west throughout Ontario but not generally through the Hudson and James Bay lowlands, through northern Manitoba and Saskatchewan, in the southwestern and northeastern portions of Alberta and northern British Columbia, widely distributed in the Yukon and Northwest Territories and also established on many arctic islands (Baffin,



Southampton, King William, Victoria, and Banks).

The lake trout has been introduced widely outside its natural range to such countries as New Zealand, South America, Sweden, and many parts of the United States. *See* Marshall and Keleher (1970) for a partial listing of introductions.

Biology A considerable fund of information has accumulated on lake trout reproduction in Canadian lakes. Lake trout spawn in the autumn but there is much variation from lake to lake and the exact date of spawning depends on such factors as latitude, weather, and the size and topography of the lake. For detailed information resulting from studies on particular lakes *see* Eschmeyer (1955), Martin (1955, 1957, 1960), McCrimmon (1958), and Rawson (1961). Throughout most of Canada, spawning occurs mainly in October, sometimes as early as September in the north or as late as November in the south; in Lac la Ronge, Sask., October 1–11 (Rawson 1961), and in lakes in Algonquin Park, Ont., October 15–31 (Martin 1957). In New York State spawning may be delayed until early December. Dates of spawning in different parts of North America were tabulated by Martin (1957).

Spawning most often occurs over a large boulder or rubble bottom in inland lakes at depths of less than 40 feet (12.2 m) and sometimes as shallow as 1 foot, but in the Great Lakes at depths less than 120 feet (36.6 m). In rare instances, spawning may occur in rivers, as observed and documented for Montreal and Dog rivers, Lake Superior, by Loftus (1958). Temperatures at time of spawning have been reported at 48° F (8.9° C) (Saskatchewan) to 51°–57° F (10.6°–13.9° C) but spawning is not initiated by temperature alone; some observers suggest light may be influential. The spawning act takes place after dark, for the trout move onto the spawning grounds at about 1900 hours and most depart by 2200.

Cleaning of the spawning grounds, noted by Martin (1957), consisted of brushing the rocks with body or tail fin, or rubbing them with the snout.

One or two males may spawn with one female, or a group of males and females may spawn together, extruding eggs and sperm over rocky bottom. The fertilized eggs fall into the crevices between the large rocks. The eggs are large, measuring 5–6 mm (in ovary) at maturity. The number of eggs deposited depends on the size of the female but ranges from 400–1200 eggs per pound of female. A 32-inch (813-mm) female from the Great Lakes may deposit up to 18,000 eggs.

There is evidence of homing, i.e., returning to the same spawning beds year after year, in some lakes (Martin 1960) but an absence of homing tendencies in others (McCrimmon 1958); even where homing tendencies exist, lake trout will utilize artificial spawning grounds (Martin 1960).

After spawning, lake trout disperse through the lake and may move over 100 miles away. The movements of trout have been studied by marking (tags or fin clipping) and much information has been gathered. They sometimes tend to wander many miles and move freely throughout small and medium-sized lakes.

The eggs remain in their rocky incubator for many weeks. Martin (1957) determined incubation periods for a number of Algonquin Park lakes and observed that, although spawning occurred October 15–30 (except in one case), hatching varied from February 15 to March 30. The period of incubation in that area varied from 15–21 weeks, and temperatures of 32.5°–33.8° F (0.3°–1.0° C) were recorded. Usually 4 to 5 months are required for incubation and hatching usually occurs in March or April, but in Great Bear Lake it is delayed until June. The young usually seek deeper water within a month or so of hatching and after the yolk sac is absorbed, but in far northern lakes they may remain in inshore waters for months or even years, as in Great Bear Lake. In the main, however, the biology of young lake trout is not well known.

The growth rate varies greatly over the whole range but in the central portion of the Canadian range, growth is fairly rapid. Aging has been done most commonly by scale examination but is difficult for ages over about 8 years. Otoliths can also be used and recently the use of the outer branchiostegal ray was recommended as a supplementary method of aging (Bulkley 1960).

Sexual maturity is usually attained about age 6 or 7, but not until age 13 in Great Bear Lake. Comparative rates of growth are shown for a number of lakes, in the table, p. 224.

Lake trout grow to weights in excess of 50 pounds in many Canadian lakes and, on one occasion at least, exceeded 100 pounds. The largest known lake trout in North America was caught in a gillnet in Lake Athabasca, Sask., on August 8, 1961, by Orton Flett. It weighed 102 pounds (46.3 kg) and was 49.5 inches (126 cm), total length. It was a relatively young fish, 20–25 years old. The rapid growth rate was probably related to the fact that it never became sexually mature, according to Dr Helen Battle, University of Western Ontario, who examined the gonads. The specimen is preserved in the ROM collection. Other specimens in excess of 80 pounds were caught in Lake Athabasca about 1961. The angling record for North America is 63 pounds 2 ounces (28.6 kg), for a trout caught in Lake Superior in 1952. In most inland lakes the average size caught by anglers is less than 10 pounds.

The lake trout occurs only in relatively deep lakes through the southern part of its Canadian range, but in the northern half, especially in the Territories, it occurs also in shallow lakes and in rivers. It is the least tolerant of salt water of all the chars, although it has been reported from coastal waters by Weed (1934), Dunbar and Hildebrand (1952), and Walters (1953, 1955). Its saltwater occurrences were reviewed by Boulva and Simard (1968) who concluded that the upper limit of salinity tolerance was between 11–13‰, but it did not enter oceanic salt water having a salinity of 35‰.

In inland lakes in southern Canada the

		Age (*years*)																								
	FL	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	>23+
Lac Mistassini, Que.	*inches*	–	–	–	8.1	9.1	12.4	14.3	16.2	16.9	19.0	19.3	20.1	21.3	20.8	20.8	20.8	21.4	20.5	22.4	22.7	20.5	23.6	23.2	24.3	–
(Dubois and	*mm*	–	–	–	205	231	315	362	412	428	483	491	511	542	528	528	528	543	521	568	576	520	599	588	618	–
Langueux 1968)																										–
L. Opeongo, Ont.	*inches*	–	–	7.7	9.5	11.0	13.1	14.4	17.4	19.4	21.3	22.8	24.3	25.4	27.8	28.7	29.4	–	–	–	–	–	–	–	–	–
(Martin 1970)	*mm*	–	–	196	241	279	333	366	442	493	541	579	617	645	706	729	747	–	–	–	–	–	–	–	–	–
	Wt (*lb*)	–	–	–	–	–	0.8	1.0	1.8	2.6	3.4	4.2	5.1	5.9	7.8	8.6	9.3	–	–	–	–	–	–	–	–	–
Louisa L., Ont.	*inches*	–	4.1	6.9	7.7	9.6	12.8	13.5	14.4	15.8	17.3	20.5	20.0	21.8	–	–	–	–	–	–	–	–	–	–	–	–
(Martin 1952)	*mm*	–	104	175	196	244	325	343	366	401	439	521	508	554	–	–	–	–	–	–	–	–	–	–	–	–
Lac la Ronge, Sask.	*inches*	–	–	10.5	14.8	16.8	20.1	21.4	23.2	24.1	25.3	26.0	27.2	27.9	29.7	31.0	32.0	32.8	35.0	36.2	–	–	–	–	–	–
(Rawson 1961)	*mm*	–	–	267	376	427	511	544	589	612	643	660	691	709	754	787	813	833	889	919	–	–	–	–	–	–
	Wt (*lb*)	–	–	–	–	–	3.5	–	–	6.3	–	8.2	–	10.4	–	14.9	16.8	–	22.5	–	–	–	–	–	–	–
Great Slave L., N.W.T.	*inches*	5.6	7.0	9.9	11.7	13.6	15.4	17.2	18.9	19.2	21.2	22.9	24.8	26.7	28.6	30.2	31.6	33.1	34.2	35.2	35.9	36.5	37.1	37.6	38.1	–
(Kennedy 1954b)	*mm*	142	178	251	297	345	391	437	480	488	538	582	630	678	726	767	803	841	869	894	912	927	942	955	968	–
	Wt (*lb*)	.05	0.1	0.3	0.5	0.8	1.2	1.7	2.3	3.1	4.2	5.3	6.7	8.4	10.3	12.2	14.0	16.0	17.8	19.3	20.6	21.6	22.6	23.6	24.5	–
	TTL																									
Great Bear L., N.W.T.	*inches*	1.1	2.5	3.9	5.3	7.1	–	–	11.5	12.6	13.9	14.7	16.2	16.2	16.6	17.7	19.2	20.3	21.9	22.6	23.9	24.7	25.8	27.6	27.5	28.3–38.0
(Miller and Kennedy	*mm*	28	63	98	134	180	–	–	293	320	354	372	412	412	420	449	487	515	556	574	607	626	656	700	698	719–965
1948a)	Wt (*lb*)	–	.01	.03	.06	–	–	–	.88	.88	1.1	1.3	1.6	1.7	1.8	2.2	3.0	3.6	4.3	5.1	5.8	6.3	6.4	7.9	8.4	8.8–34.0

depth–distribution of lake trout varies with the seasons. In autumn, usually early October, they move into rocky shallows in preparation for spawning. After spawning is completed they disperse freely throughout the lake at various depths and remain dispersed throughout the winter months. In spring they often occur in surface waters immediately after breakup of ice. As surface waters warm with the advance of spring, lake trout retire to the cooler waters, eventually retreating to the hypolimnion, below the thermocline during the warmer summer months. The depth of the thermocline in a particular lake depends on many factors such as latitude, size of lake, height of surrounding land and, hence, protection from wind, but in most small lakes it occurs at depths of 40–60 feet (12.2–18.3 m). Lake trout do make excursions above the thermocline despite the unfavourably warm temperatures. In general, they prefer temperatures of about 50° F (10° C).

In large lakes, they tend to inhabit deeper water. In Lake Superior, Dryer (1966) noted they were most common at all seasons at depths of 60–175 feet (18.3–53.0 m) although there was evidence of seasonal movement.

Lake trout are predaceous and feed upon a broad range of organisms including freshwater sponges, crustaceans, aquatic and even terrestrial insects, many species of fishes (including lake trout), and even small mammals. Food consumed varies with the season, particularly in small inland lakes. In Lake Louisa, Algonquin Park, Ont., Martin (1954) demonstrated that they ate largely plankton in summer because the only forage fish (minnows) were in shallow water and unavailable to them, restrained as they were in cooler, deeper waters by a thermal barrier. But, trout that feed on plankton are slower growing, smaller, and do not live as long as those that feed mainly on fishes (Martin 1966). Invertebrates, particularly *Mysis relicta* and *Pontoporeia*, are important, especially in the diet of young trout.

Ciscoes (subgenus *Leucichthys* spp.) appear to be the preferred natural food of adults of most populations (Rawson 1959, 1961; Dryer et al. 1965; Martin 1970; MacCrimmon and Skobe 1970). Other fishes eaten include whitefish, smelt, perch, sculpins, emerald shiners, ninespine sticklebacks, troutperch, and longnose suckers, to name a few of the many species observed in stomachs.

Although ciscoes appear most commonly in the diet of large trout, other fish species may dominate in certain lakes. In Lake Ontario, the alewife was of primary importance to adult trout (Dymond 1928b) and in Lake Superior the introduced smelt became the most important food fish in 1963, although whitefishes (*Coregonus* spp.) remained seasonally important during October–December (Dryer et al. 1965).

Organisms eaten depend, to some degree, upon availability, and lake trout seem able to take advantage of an abundance of almost any food. In northern Quebec, near Knob Lake, Bleakney (1954) found trout stomachs distended with mosquito larvae and pupae, but the trout were considered to be in poor condition. In the Ungava Bay region of northern Quebec, ". . . mice and shrews are quite often found in the stomach of the lake trout, . . ." (Dunbar and Hildebrand 1952), and similar observations on food in Ungava were reported by Harper (1961). In Lake Opeongo, Martin (1970) noted that the freshwater sponge (*Spongilla*) was commonly found in trout stomachs.

The role of sculpins as food of lake trout warrants special mention. In Lake Michigan, cottids (*Myoxocephalus quadricornis, Cottus ricei, C. cognatus*) were a significant item of diet, and the most important fish component in the diet of trout under 15 inches (381 mm) long (Van Oosten and Deason 1938). In Lake Ontario, although only large lake trout were examined, cottids (especially *M. quadricornis*) were a significant item of food (Dymond 1928b). In Lac la Ronge, Rawson (1961) noted that "The deepwater sculpin is apparently one of the first fish of suitable size and in suitable location to provide food for young trout." Although the lake trout apparently disappeared entirely from Lake Michigan, probably in large measure because of sea lamprey predation, its disappearance from Lake Ontario is more puzzling, for sea lamprey and lake trout had cohabited Lake Ontario for centuries, as they had in Seneca and Cayuga lakes in New York. Perhaps it is significant that the once dense populations of deepwater sculpins have disappeared from Lake Ontario and that none have been seen since 1959–1960.

The lake trout has relatively few enemies under natural conditions, but those in the upper Great Lakes were apparently unable to survive predation by sea lampreys which gained access to the upper lakes by the man-made Welland Canal (*see* under sea lamprey for history and details).

Lake trout eggs are susceptible to predation. Eggs of river-spawning populations in Lake Superior were consumed by round whitefish, according to Loftus (1958), who observed as many as 150 eggs in a single round whitefish stomach. The brown bullhead is another serious predator on lake trout eggs, especially in inland lakes of southern Ontario. In Manitoba, burbot under 3 pounds (1361 g) were reported to eat lake trout eggs (Anon. 1960). Although burbot and lake trout are known to compete for the same food items, extensive studies in Lake Michigan before the disappearance of both species gave no evidence that they fed on each other (Van Oosten and Deason 1938). Occasionally, lake trout become cannibalistic, and will eat smaller lake trout (Martin 1970) and even their own eggs.

Parasites of lake trout in Algonquin Park lakes in Ontario were studied by MacLulich (1943a), who described a new species of tapeworm, *Proteocephalus parallacticus*, which occurred in the intestines of most trout. Hundreds of lake trout from 34 lakes in Algonquin Park were also examined by MacLulich (1943b) who noted 13 species of parasites. The large tapeworm *Eubothrium salvelini* occurred in 85% of lake trout examined. A species of *Diphyllobothrium* occurred frequently in lake trout of some lakes, encysted in the viscera, not in the flesh as is *D. latum*. Transmission of the cestode *Diphyllobothrium* sp. to lake trout in Algonquin Park was studied by Freeman and Thompson (1969) who demonstrated that infection was not always a result of heavy plankton consumption, as previously thought. Rather, they suggested ". . . a suitable species of first fish host probably accounts for much of the higher levels of infection in lake trout in some lakes, although direct transmission from copepods to lake trout may account for the more sparse infections in other lakes."

In addition to the above, Bangham and Venard (1946) also studied parasitism in Algonquin Park lakes, and Bangham and Adams (1954) examined specimens from the Fraser River drainage of British Columbia. Four species of parasites were reported from Lake Huron lake trout by Bangham (1955).

From Wollaston Lake in northern Saskatchewan, Rawson (1959) reported *Eubothrium salvelini*, *Echinorhynchus salvelini*, *Glaridacris catostomi*, and *Schistocephalus solidus* in lake trout. The nematode *Cystidicola stigmatura* was reported by Rawson (1961) from northern Saskatchewan.

From Great Bear Lake, N.W.T., Miller and Kennedy (1948a) reported a similar list of parasites plus *Triaenophorus crassus*, *Diphyllobothrium latum*, *Echinorhynchus coregonini*, *Salmincola siscowet* and leech, *Piscicola milneri*.

Triaenophorus crassus has been found encysted in the flesh of lake trout from many parts of northern Canada including northern Saskatchewan and the Northwest Territories, but infection rates are usually low. *See* under lake whitefish for additional information on *T. crassus*.

Relation to man The lake trout is highly prized both as a game fish and as a commercial species. In some lakes (Lac la Ronge, Sask., Rawson 1961) lake trout are harvested by both commercial and sport fishermen, but where conflicts arise, the resource usually benefits more people when harvested by anglers.

As a game fish in southern Canada, it is caught by fly or spin fishing early in the spring, immediately after breakup of the ice, or by deep trolling with a metal line later in the summer. In the far northern lakes, including those in the Northwest Territories, lake trout remain in surface waters throughout the summer and deep trolling is unnecessary. It is also the object of intense winter fishing through the ice in many parts of Canada. This winter harvest may require greater management control, particularly for lakes that are heavily fished in summer as well as in winter.

Commercially, the lake trout is caught by gillnets. It is a valuable species but the yield has been greatly reduced.

In northern Canada, especially in the Northwest Territories, lake trout fisheries have become increasingly important, supplying the demand of eastern markets that were formerly dependent on Great Lakes stocks. The total Canadian commercial yield of lake trout has declined however, as shown by the take for the years 1964–1968 inclusive:

Year	1964	1965	1966	1967	1968
Thousands of pounds	3384	3176	2984	2941	2390

The famous commercial lake trout fisheries of the Great Lakes have been decimated by the sea lamprey and by pollution, particularly DDT. The latter accumulates in fatty tissues, especially in the yolk of the egg and induces the death of the embryo following yolk absorption. Natural reproduction by lake trout is seriously affected in areas of high DDT concentration (Burdick et al. 1964; Johnson 1968).

Management practice has included the use of hatcheries for artificial propagation. Lake trout are caught in poundnets on the spawning grounds, the eggs and milt stripped and the adults released. The fertilized eggs are reared in hatcheries to the fingerling or even yearling stage, and released. The planting of hatchery stock has been shown to be effective in the Great Lakes. In Cayuga Lake, N.Y., hatchery stock has been vital in the maintenance of the fishery for at least 50 years (Webster et al. 1959).

The lake trout is an esteemed food fish. The flesh may be white, pink, orange or orange-red, the colour being influenced in part, at least, by diet; large piscivorous trout often have white flesh. Irrespective of colour, the flavour is usually excellent. It is most often eaten fresh, but is sometimes smoked and a small amount is canned. The fat lake trout (siscowets) from the deep waters of Lake Superior were edible only when smoked.

Nomenclature

Salmo Namaycush	— Walbaum 1792: 68 (type locality Hudson Bay)
Salmo pallidus	— Rafinesque 1817b: 120
Salmo amethystus (frequently misspelled *amethystinus*)	— Mitchill 1818b: 410
Salmo namaycush (Pennant)	— Richardson 1836: 173
Salmo confinis	— DeKay 1842: 238
	— Adams 1873: 237
Salmo ferox	— Perley 1852: 196
Cristivomer namaycush	— Gill and Jordan *in* Jordan 1878c: 356
Salvelinus namaycush	— Jordan and Gilbert 1883a: 317
	— Miller 1950b: 3

(*See* La Rivers 1962, for additional details of nomenclature)

Etymology *Salvelinus* — an old name for char; *namaycush* — an Indian name.

Common names Lake trout, Great Lakes trout, mackinaw trout, salmon trout, laker, namaycush, masamacush, togue, grey trout, Great grey trout, Great Lakes char, landlocked salmon, mountain trout, taque. French common name: *touladi.*

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Subfamily Coregoninae Whitefishes, round whitefishes, ciscoes, with an orbitosphenoid, dermosphenotic, and hypethmoid; without suprapreopercle or epipleurals; maxilla without teeth; parietals meet at midline; 15 or fewer dorsal fin rays; eggs small, a postlarval stage, young usually without parr marks (but present in *Prosopium*).

Some authors accord family rank to the whitefishes and refer to the group as the Coregonidae, but we have chosen to consider them as a subfamily of the family Salmonidae, as suggested by Norden (1961a).

This group of fishes is the most widely distributed and, taxonomically, the most perplexing of all Canadian freshwater fishes. In this work, we recognize 18 species, in 3 genera, as follows: *Stenodus* (1 species), *Prosopium* (3 species), and *Coregonus* (14 species). It is within the genus *Coregonus* that the most difficult taxonomic problems arise, particularly with those whitefishes in which the upper and lower jaws are more or less equal and which have more than 32 gill rakers. These whitefishes, with terminal mouths and high gill raker counts, are called ciscoes or lake herrings. Until about 1960, these fishes were grouped in the genus *Leucichthys*, but studies by Norden (1961a) indicated that they more properly belonged in the genus *Coregonus* (subgenus *Leucichthys*). Few ichthyologists would agree on the exact number of species of ciscoes in Canadian waters, because they are so exceedingly difficult to identify. Some recent authors (McPhail and Lindsey 1970) referred to one of the most variable species (or species groups), *Coregonus artedii*, as "*C. artedii*" complex, in recognition of the difficulty of affixing a precise name to its members.

The difficulties in identification are directly related to the variability of whitefishes from lake to lake, variability in such features as shape, size, growth rate, and numbers of scales and gill rakers, characters that are directly influenced by the environment. Thus, the basic plan of each species (its genotype) is modified by the environmental conditions existing in each body of water. To identify ciscoes in the Great Lakes, it is wise to consider the variation of related species in the same lake, for characters that clearly distinguish two species in one lake may not be reliable in another. (*See* Scott and Smith 1962; Smith 1964a.)

While some species of ciscoes are wide ranging, like *C. artedii*, others are restricted in distribution. For example, within the Great Lakes basin there are five species of ciscoes that, as far as we know, are restricted to the Great Lakes basin and apparently do not occur anywhere else. These endemic ciscoes live (or did live, until recent years) in the deeper waters of the Great Lakes. The five species are listed below, more or less in order of size:

deepwater cisco, *Coregonus johannae*
longjaw cisco, *Coregonus alpenae*
shortnose cisco, *Coregonus reighardi*
kiyi, *Coregonus kiyi*
bloater, *Coregonus hoyi*

All five occurred only in lakes Huron and Michigan, four occurred in Lake Superior, three in Lake Ontario, two in Lake Nipigon, and one in Lake Erie.

Canadians have taken little interest in these Great Lakes endemic species, either commercially or biologically. No serious studies of any of them have been conducted in Canada since the period of intense activity stimulated in the University of Toronto during the 1920's and 1930's when Bensley, Dymond, and their students and colleagues, investigated the fishes of lakes Ontario, Erie, and Nipigon. Thus, with few exceptions, data resulting from Canadian studies on Great Lakes endemic ciscoes are 30 years old or more. In fact, few morphometric or meristic data have been published by anyone in the last 20 years, for attention has been directed more and more toward changes in the ecology of the Great Lakes and, in particular, changes in population levels of the different species.

In addition to the endemic deepwater ciscoes, there were two other species of ciscoes that lived in deep water, the blackfin cisco, *C. nigripinnis*, and the shortjaw cisco, *C. zenithicus*. These two species, together with the five endemic ciscoes, were collectively known as "chubs." Thus, "chubs" were ciscoes of the genus *Coregonus* (subgenus *Leucichthys*), exclusive of *Coregonus artedii*, but comprising seven species (in descending order of size: *nigripinnis, johannae, zenithicus, alpenae, reighardi, kiyi, hoyi*). These were seldom identified to species but were simply marketed as "chubs," and reached the consumer almost exclusively as smoked fish. The principal market, indeed the principal fishery, was in the United States where the product was considered a delicacy. It was seldom sold in Canada.

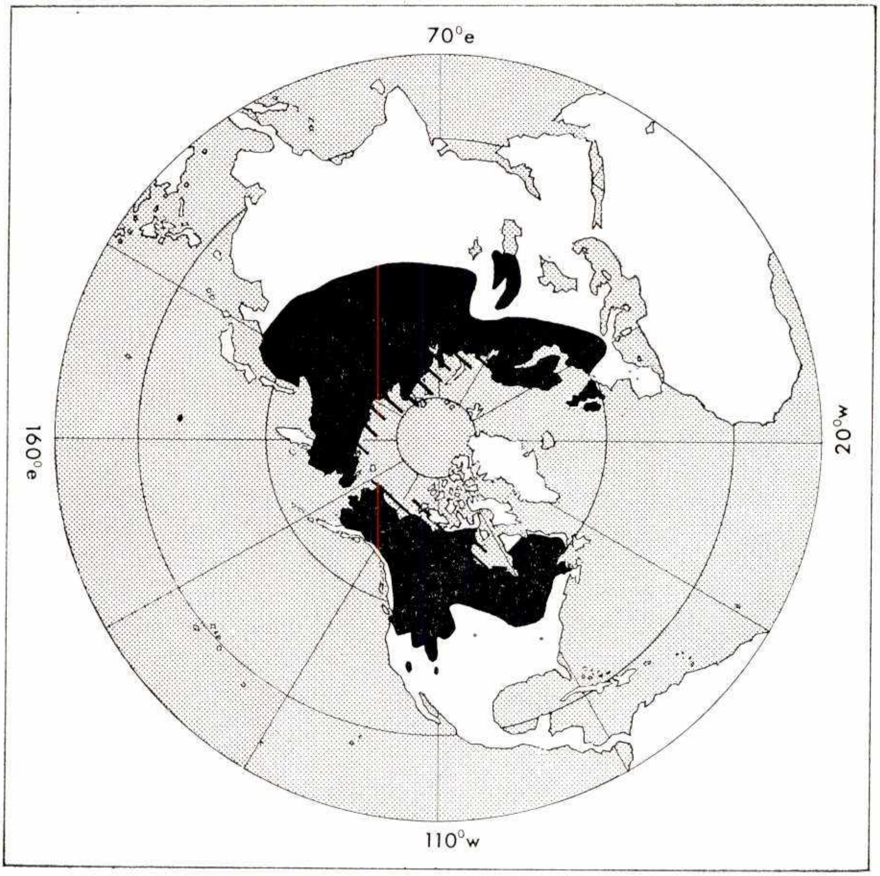
Until about 1950, the Great Lakes supported a substantial chub fishery. Chubs were caught exclusively by gillnets set in deep water. The larger, fatter chubs were preferred, especially the species *nigripinnis*, *johannae*, and *alpenae*, but as these became scarce, *zenithicus* and *reighardi* were caught in increasing numbers and finally the smaller species, *kiyi* and *hoyi*, which were originally spurned, entered the fishery. The chub fishery, as such, ceased to exist before 1960, and today, the bloater, *C. hoyi*, is really the only species supplying this traditional smoked fish market.

The history of the whitefish and cisco fisheries of the Great Lakes is one of increasing exploitation and dwindling stocks. As the catches decreased, the amount of gear fished increased, so that a review of the annual poundage caught does not indicate the decline in catch per unit effort. In a repetitive fashion, each fishery declined and finally collapsed, and although many explanations for the declines have been given, of which predation by the sea lamprey is the most common, some fisheries, at least, declined and vanished without apparent relation to sea lampreys. The Lake Erie cisco and whitefish fisheries are good examples. It was naive to expect that any population of organisms could withstand such continuous and intense exploitation at the same time that the habitat was being destroyed by such activities as gravel removal, gas well drilling, and sewage discharge.

Much of our knowledge of the ecology of the Great Lakes ciscoes was gathered before the drastic changes occurred in the species composition of the Great Lakes — changes wrought in large measure by intense commercial fishing, by reduction in the populations of lake trout and burbot because of sea lamprey predation, but aided and intensified by environmental degradation.

As a result of breakdown in the established ecological structure, the populations of the endemic species, particularly the larger ones, have been drastically affected and many species no longer occur in lakes where they once supported substantial fisheries. (*See* papers by Moffet 1957; Smith 1964a, 1968.) For example, *C. nigripinnis*, *C. reighardi*, and *C. kiyi* have not been seen in Lake Ontario for many years. *C. johannae* and *C. alpenae* have presumably disappeared from Lake Huron. All five endemic species, except *C. hoyi,* have apparently disappeared from Lake Michigan.

Associated with the disappearance of familiar species is the appearance of ciscoes in deep water which differ morphometrically from those that previously lived there. The deepwater ciscoes have been difficult to identify in the past, but in recent years have become even more so. This phenomenon was thoroughly discussed by Smith (1968), who noted that many of the "new" ciscoes resembled *hoyi* but were more robust than that species used to be. Other "new" ciscoes resembled *C. artedii* but were also more robust and tended to be deeper bodied. Smith noted also that differences in morphological measurements and counts were irregular and that the new forms exhibited complete gradation into the typical appearance of the species they resembled. Some biologists believe that introgressive hybridization (that is, interbreeding and back crossing) has been taking place and species that become rare, in the absence of mates of their own kind, have been hybridizing with the more common *hoyi* and *artedii*. In any case, ciscoes in the Great Lakes seem to have changed considerably since the publication of the *Coregonid Fishes of the Great Lakes* by Walter Koelz (1929), and whitefishes in inland waters continue to confound us and to defy ready taxonomic placement. Hence, the following descriptions for all members of the genus *Coregonus*, but especially the ciscoes or lake herrings (subgenus *Leucichthys*), are general, except where noted otherwise, and cannot be regarded as rigid delimitations of the species throughout its range. Additional descriptive references are given whenever possible.



World Distribution of the Whitefishes

Comparative table for Great Lakes ciscoes

	Lake	Depth range (*fath*)	Month(s) of spawning	Gill raker range	Avg length (*mm*)
alpenae —	Erie (rare)	3–34	November	30–39	245
	Huron	14–100	November	31–44	380
	Michigan	5–90	November	33–46	380
artedii —	Ontario	0–75	November – early December	41–54	250
	Erie	0–32	November– early December	38–53	375
	Huron	0–35	November– early December	40–53	300
	Superior	0–90	November– early December	38–53	250
	Over whole range	0–90	September–December	38–64	375
hoyi —	Ontario	16–75	between November and March (but uncertain)	39–50	>200
	Huron	0–100	February (uncertain)	37–47	<200
	Michigan	0–90	March	37–48	>200
	Superior	15–90	after December (but uncertain)	37–49	<200
	Nipigon	15–54	unknown	40–48	<200
johannae —	Huron	15–100+	late August–September	25–35	300
	Michigan	30–90	mid-August–end Sept.	26–36	300
kiyi —	Ontario	20–75	August	41–48	230
	Huron	60+	October–November (uncertain)	36–44	<200
	Michigan	30–90	October	34–45	230
	Superior	40+	late November– early December	36–45	<200
nigripinnis —	Ontario	max 60 1 spec.	(January)	–	–
	Huron	35–100+	late November–Dec.	40–52	250–350
	Michigan	30+	late December–early Jan.	41–52	250–350
	Superior	15–100+	September–early October	36–48	250–350
reighardi —	Ontario	20–75	early May	33–42	240–295
	Huron	–	–	–	information not available
	Michigan	6–90	May, early June	30–43	<240
	Superior	0–65	October–early November	32–42	250
	Nipigon	10–30+	November	32–38	<240
zenithicus —	Huron	14–100	mid-September, October	34–44	<300
	Michigan	12–90	October, November	35–44	<300
	Superior	11–100	late November, early December	32–46	<300
	Nipigon	6–54	late October, early November	33–42	<300

North American Distribution of Ciscoes,
Subgenus Leucichthys

LONGJAW CISCO

Coregonus alpenae (Koelz)

Description Body elongate, average total length about 10.5 inches (267 mm), compressed laterally but robust, greatest body depth in front of dorsal fin, 23–27% of total length. Head heavy, broad and short, 20–25% of total length; eye moderate, its diameter smaller than snout; snout broad, somewhat rounded; mouth terminal, lower jaw heavy, usually projecting beyond upper jaw, maxillary usually not pigmented, extending posteriorly to beyond the anterior margin of eye. Gill rakers 30–39 (Lake Erie), 33–42 (Lake Huron) and 31–44 (Lake Huron), 33–46 (Lake Michigan). Branchiostegal rays 8–10 (Lake Huron). Fins (all fin ray counts from Lake Erie): small dorsal adipose present; dorsal 1, rays 10–13; caudal distinctly forked; anal rays 10–14; pelvic rays 10–13; pectoral rays 13–16. Scales cycloid, large 68–83 in lateral line. Vertebrae 56–59.

Nuptial tubercles developed on breeding males.

(*See* Koelz 1924, 1929; Scott and Smith 1962.)

Colour Overall colouration silvery with pink or purple iridescence, green or blue on back, silvery on sides and white below. Pigmentation on jaws and fins very light.

Systematic notes This endemic deepwater cisco was described by Koelz (1924). The holotype is a female (immature), 10.6 inches (269 mm) in standard length, caught in Lake Michigan, June 15, 1923, at a depth of 150–282 feet (45.7–86.0 m). It is in the United States National Museum, cat. no. 87352, and was in good condition when examined in 1959.

Distribution The longjaw cisco is indigenous to the Great Lakes basin and occurred only in lakes Huron and Michigan. Evidence of a small population in Lake Erie was published recently (Scott and Smith 1962), but it is most unlikely that the species still survived in Lake Erie in 1970. The species was also decimated in Lake Michigan and must be near extinction there.

Biology Spawning apparently took place in November in lakes Michigan and Huron, according to the evidence available, although females with ripe eggs were reported as early as July and spawning as early as October 16 (Jobes 1949a). This early ripening of occasional individuals has been noted for other deepwater ciscoes. Koelz (1929, p. 376, 377) reported on his finding, in late November, 1919, of females with freely flowing spawn, and pearl organs on males of longjaws, taken in Colpoys Bay, Georgian Bay, Lake Huron. It must be noted that the observations on which this report was based were made 5 years before the species was described, although Koelz was undoubtedly familiar with the species. The depth of spawning was not precisely known. Koelz (1929) believed spawning to occur at 60–150 feet (18.3–45.7 m) in Lake Michigan, but it was possibly deeper.

Age analyses, using scales, indicated a relatively rapid rate of growth for the longjaw. Males and females grew at about the same rate and sexual maturity was usually attained at age 3 or 4. Lake Michigan fish attained a weight of about 6.1–6.4 ounces and a length of 11 inches (279 mm) at age 4 and about 12 inches (305 mm) at age 5. In his original description, Koelz (1924) noted that individuals did not usually attain a length of 15 inches (380 mm) or a weight of 2 pounds. Lengths at various ages for lakes Michigan and Erie are shown below:

	Total tip length			
Age	L. Erie, Ont. (Scott and Smith 1962)		L. Michigan (Jobes 1949a)	
	(inches)	*(ɯɯ)*	*(inches)*	*(mm)*
1+	5.1	130	–	–
2+	8.6	218	10.9	277
3+	10.6	269	11.5	292
4+	12.7	323	12.0	305
5+	–	–	12.8	325
6+	–	–	14.0	356
7+	–	–	14.8	376
8+	–	–	16.6	421
9+	–	–	17.3	439

In Lake Huron the longjaw cisco was considered to live at depths of 300–360 feet (94.4–112.7 m) (Koelz 1924, said they were most abundant at depths less than 360 feet) except possibly during spawning, when there was an apparent movement into waters of at least half this depth. There is some minor discrepancy in the available literature concerning preferred depths. Jobes (1949a) found the species most abundant at depths less than 420 feet (128 m) but recorded finding it as deep as 582 feet (177 m). In Lake Erie, most captures were made at depths of about 200 feet (31 m) but it was caught in waters as shallow as 60 feet (18.3 m) (Scott and Smith 1962).

Few food studies have been conducted, but the contents of 30 stomachs of this cisco from Lake Michigan were reported by Koelz (1929). *Mysis relicta* appears to have been the principal food, but occasionally bottom invertebrates such as fingernail clams and aquatic insect larvae were eaten. Koelz's conclusions were recently substantiated by Bersamin (1958) who considered that *Mysis* made up 95% of the food of *alpenae* in Lake Michigan, the remaining 5% consisted of *Pontoporeia.* As many as 458 *Mysis* were counted in a single stomach.

The longjaw formed part of the food supply of the lake trout and burbot populations before these fishes were decimated by the sea lamprey, and it seems likely that the lamprey preyed on longjaw also. It was also the object of intensive commercial fishing.

Bangham (1955) examined one specimen of longjaw cisco from the North Channel of Lake Huron and found it to be infected with the trematode *Diplostomum* sp., and acanthocephalan *Echinorhynchus salmonis*.

Relation to man The longjaw was one of the deepwater ciscoes preferred by the smoked fish trade and, hence, was important in the chub fishery. It is probably extinct or nearly so in Lake Michigan, but its status in Lake Huron is not known. It has not been seen in Lake Erie since 1957. For additional information *see* section on chubs and deepwater ciscoes p. 230–231.

Nomenclature

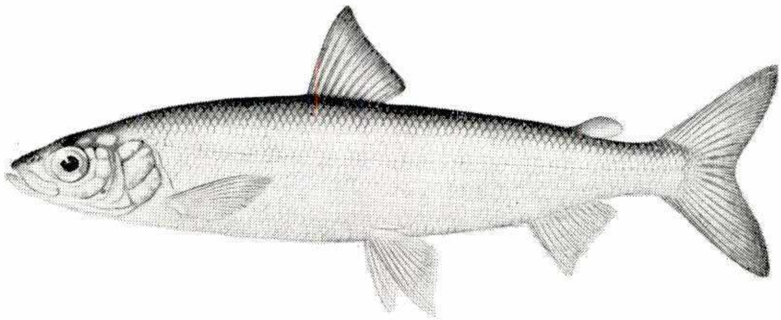
Argyrosomus prognathus	— Evermann and Smith 1896: 314
Leucichthys johannae	— Jordan and Evermann 1911: 24
Leucichthys alpenae	— Koelz 1924: 1–5 (type locality Lake Michigan off Ile aux Galets, 22 miles NE of Charlevoix, Mich.)
Coregonus alpenae (Koelz)	— Hubbs and Lagler 1958: 54
	— Scott and Smith 1962: 1013

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *alpenae* — probably named after town of Alpena, Mich.

Common names Longjaw cisco, longjaw, longjaw chub. French common name: *cisco à grande bouche*.

CISCO, LAKE HERRING

Coregonus artedii Lesueur



Description Body elongate, total length 8–12 inches (203–305 mm) variable from lake to lake, compressed laterally, greatest body depth in front of dorsal fin, 20–30% of total length (but body depth most variable, females deeper bodied than males). Head length about 20–24% of total length; eye moderate, its diameter 21–26% of head length; snout usually longer than eye; mouth terminal, lower jaw often projecting slightly beyond upper, but jaws may be equal or upper protruding slightly when mouth closed, maxillary extending posteriorly to below anterior half of eye. Gill rakers, range in total count, 38–64, but 41–54 (Lake Ontario), 38–53 (Lake Erie, Lake Superior), 41–57 (Lake Nipigon), 54–64 (*C. nipigon* in Lake Nipigon), 41–50 (Great Bear Lake). Branchiostegal rays 7–9 (Great Lakes), 7–10 (Great Bear Lake). Fins: small dorsal adipose present; dorsal 1, rays 10–15; caudal distinctly forked; anal rays 11–15; pelvic rays 11 or 12, pelvic axillary process present; pectoral rays 14–18. Scales cycloid, large, 63–94 in lateral line (63–81 in Lake Erie). Vertebrae 50–63 (50–60, Lake Erie; 56–63, McPhail and Lindsey 1970).

Nuptial tubercles or pearl organs well developed on scales of breeding males, one appearing on the centre of each scale and on most rows above and below the lateral line.

(*See also* Dymond 1926; Koelz 1929, 1931; Dymond 1943; Scott 1950; Kennedy 1953a; McPhail and Lindsey 1970.)

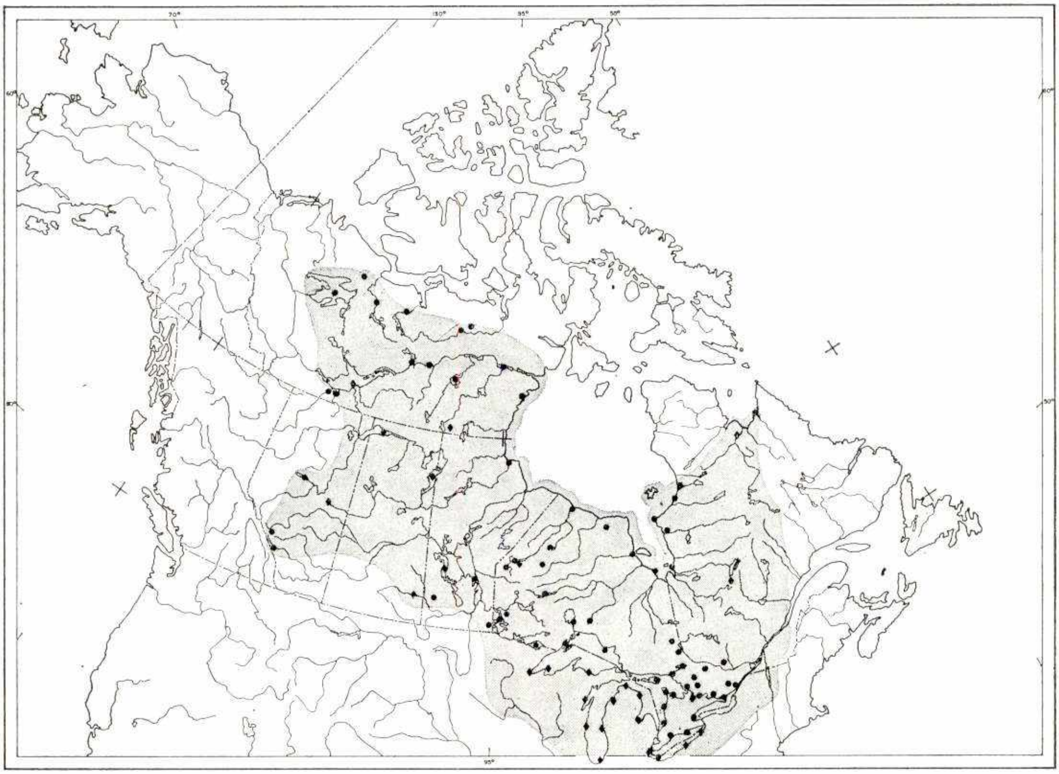
Colour Overall colouration is silvery with pink to purple iridescence. The colour of the back varies greatly from lake to lake (or population to population in large lakes) from almost black to nearly any shade of blue or green to gray or light tan (whence such names as blueback and grayback); silvery on sides and white below. All fins more or less clear but pelvics and anal milky or opaque on adults and usually only lightly sprinkled with black pigment, if at all; remaining fins, especially dorsal and caudal, with varying amounts of dark pigment, sometimes densely concentrated on outer half or on margins.

Systematic notes The lake herring, or cisco, was named by Lesueur (1818a), based on specimens from "Lake Erie and Lewiston upper Canada." The type is not extant but an extensive discussion of Lesueur's description and the type locality (Lake Erie is above Niagara Falls, Lewiston is below, and ciscoes caught there would probably be Lake Ontario stock) was given by Koelz (1929, p. 476, 477), who restricted the name *artedi* to the slender form. The species has now been decimated from Lake Erie and still persists, although at low population levels, in Lake Ontario. Fortunately, there are large reference collections from both lakes available in the Royal Ontario Museum and the Museum of Zoology, University of Michigan.

The great variability in morphometry, meristics, and general appearance, in addition to its very extensive range, have led to a large number of synonyms. Twenty-four subspecies were described by Koelz (1931) who used the Lake Michigan form as representative of typical *artedii*, an action that seems regrettable for many reasons. In any case that population, too, is nearly extinct. A few authors continue to recognize subspecies, particularly in the Great Lakes region. Hubbs and Lagler (1964) listed 22 such subspecies, many of which were restricted to only one or two lakes. Such an approach to the taxonomy of this wide-ranging and variable species is totally unrealistic. If this same approach were followed throughout the extensive Canadian range the result would be taxonomic chaos. Within the Great Lakes, the validity of the subspecies is probably now an academic question anyway which will never be satisfactorily answered, for the populations have been altered too drastically and some have become extinct (*see* p. 230–231).

In an attempt to treat the problem from a broad, rather than narrow, approach, McPhail and Lindsey (1970) considered the lake herring to be a species complex and referred to it as *"Coregonus artedii"* complex. In an extensive discussion, they identified the northwestern species included in their complex with which, in the main, we agree. But the evidence for including *C. macrognathus*, *C. entomophagus* and *C. athabascae* in *artedii* rather than *zenithicus* is unconvincing (*see C. zenithicus* p. 265).

In addition to the species included by McPhail and Lindsey in this species group, we include *Coregonus nipigon*, a form described by Koelz (1925) from Lake Nipigon, Ont. Most deep-bodied ciscoes, having high gill raker counts, are assigned to this species because available keys indicate *C. nipigon* if gill rakers add up to 54 or more (Dymond 1947), or 56–59 (Hubbs and Lagler 1964).



To our knowledge *C. nipigon* specimens under 10 inches (254 mm) total length have seldom been seen, their biology is unknown, and spawning populations have never been located. In his original description, Koelz noted that the species resembled the *tullibee* of Richardson from Pine Island Lake but that the inadequate description of that species did not permit him to make a comparison. We considered that Richardson's *tullibee* of Pine Island Lake, Man., (redescribed by Dymond 1928a) also belonged to the wide-ranging *C. artedii.*

Coregonus artedii is a problem species or species group in great need of critical review, the more so because of its commercial importance. Although we have not adopted the terminology *"Coregonus artedii"* complex of McPhail and Lindsey, we are in complete agreement with the thought it conveys.

Distribution This species has the most extensive North American distribution of any cisco, since it is found in the north-central and eastern United States and throughout most of Canada. It occurs from eastern Quebec to Hudson Bay, where it enters coastal salt water and even occurs in ponds on many of the islands, through the Great Lakes system and in innumerable inland lakes through Quebec, Ontario, Manitoba, Saskatchewan, and Alberta, north into the Northwest Territories and, in the Mackenzie River system, north at least to Great Bear Lake. McPhail and Lindsey (1970) noted that it had not been reported from the Peace or Liard River systems.

Biology The biology of this species is better known than that of any other cisco. Many studies have been made in a number of inland lakes as well as in the Great Lakes proper. Two of these are particularly important because they are comprehensive and have been so frequently quoted in subsequent studies — *Life history of the lake herring*

(*Leucichthys artedi Le Sueur*) *of Lake Huron as revealed by its scales, with a critique of the scale method*, by John Van Oosten (1929), and *Morphometry of the cisco, Leucichthys artedi (Le Sueur) in the lakes of the northeastern highlands, Wisconsin*, by Ralph Hile (1937). The wealth of published data, however, discourages summarization and the interested student should consult the *Suggested Reading* section as well as the literature cited.

Like most coregonines, spawning takes place during times of declining temperatures in the fall of the year, the exact date depending upon water temperature. Large schools or aggregations are formed during spawning. In the Great Lakes and surrounding waters, spawning occurs in late November or early December, but farther north, in the Hudson Bay region, it may take place as early as September (Dymond 1933). The lake herring usually spawns a week or two after the lake whitefish. In small inland lakes, spawning is usually underway when ice begins to form around the shores, making it difficult to study and observe spawning behaviour. In Wisconsin, Cahn (1927) noted that spawning occurred at temperatures around 39.0°–41.0° F (4.0°–5.0° C) but reached its peak at 37.9° F (3.3° C). Spawning will take place, however, even if the temperature does not drop to 39.0°–41.0° F (4.0°–5.0° C). The question of delayed spawning was thoroughly discussed by John (1956).

In inland lakes, spawning usually takes place in shallow water, 3–10 feet (1–3 m) deep over almost any kind of bottom but often over a gravel or stony substrate. In the Great Lakes, spawning may occur in shallow water (Pritchard 1931; Smith 1956) or at much greater depths and even pelagically in midwater 30–40 feet (9–12 m) below the surface, in water 210 feet (64 m) deep (Dryer and Beil 1964). Males always move onto the spawning grounds a few days before the females and may leave before they do, or may remain for a few days after the females have left. Apparently the presence or absence of postspawning males on spawning grounds is dependent upon such factors as the sex ratio of the population, and weather conditions. Stormy weather will drive spawners off the grounds and into deeper water. The date of spawning is primarily temperature dependent and is, therefore, predictable in small inland lakes but may vary in larger lakes where different conditions in various parts of the lake provide optimum spawning conditions at slightly different times.

It is during the fall spawning aggregations that ciscoes are most readily caught and, in unpolluted and unexploited areas, may occur in exceedingly large numbers (*see* section *Relation to man*).

The eggs are deposited on the bottom and abandoned by the parents. The size of the eggs measured on removal from the body cavity of partly spent Lake Erie females in 1947 and 1948 ranged in diameter from 1.8–2.1 mm. Fecundity studies of ciscoes in the Great Lakes region suggest that the number of eggs is positively correlated with size, the larger females producing the greater number of eggs, but there is wide variation. On the average, a 12 inch (305 mm) female from Lake Ontario produced about 22,000 eggs, from Lake Erie about 29,000, and from Lake Superior about 6000. (Stone 1938; Scott 1951; Dryer and Beil 1964).

Development of the eggs proceeds slowly at the low winter temperatures. It is unlikely that hatching occurs under the ice in the southern parts of Canada, although few careful studies have been made; rather, the work of John and Hasler (1956) indicated that hatching did not occur until after the spring breakup of surface ice. For a discussion of factors affecting hatching, *see* John and Hasler (1956), who demonstrated that the young larval ciscoes began to feed before the yolk sac had been absorbed and that at the time of hatching they could survive 20 days of starvation, possibly a few days longer at lower temperatures.

Developmental stages of eggs and larval stages to 17.5 mm long were described and illustrated by Fish (1932) but were described in much greater detail by Pritchard (1930) who worked on Lake Ontario. The survival and development of eggs at various temperatures were studied by Colby and Brooke (1970) who concluded that the optimum incubation temperature under experimental conditions was 42.1° F (5.6° C). At this temperature, 92 days were required for hatching, but 106 days were required at 41.0° F (5.0° C), and 236 days at 32.9° F (0.5° C). Scales first develop above the anal fin, near the lateral line and have been observed on specimens only 34 mm long (Hogman 1970). Scales of Lake Huron ciscoes were critically studied by Van Oosten (1929), who demonstrated the validity of the scale method of age determination clearly and graphically. Few fishes have scales as easy to age or "read" as lake herrings of ages 1–3 years.

Growth characteristics of lake herring from many parts of Canada have received critical study. In general, males and females grow at about the same rate, although females tend to live longer and may reach a larger size. Ciscoes in Great Bear Lake have been reported to reach 13 years of age (i.e. in their 14th year). Maturity is attained at different ages in different populations, sometimes at age 2, usually age 3 or 4, but not

		Age (*years*)										
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
L. Ontario (Pritchard 1931)	FL											
	inches	5.6	8.3	9.7	10.1	10.8	11.5	12.9	13.6	16.3	–	–
	mm	142	211	246	257	274	292	328	345	414	–	–
	Wt (*oz*)	1.1	3.7	5.6	6.4	7.6	10.7	17.2	16.0	26.5	–	–
South Bay, L. Huron, Ont. (Keleher 1953)	SL											
	inches	–	6.2	8.2	8.2	8.4	–	–	–	–	–	–
	mm	–	156	209	208	212	–	–	–	–	–	–
Bay City, L. Huron, Mich. (Van Oosten 1929)	TL											
	inches	–	8.2	9.1	9.4	9.7	10.2	10.8	11.5	–	–	–
	mm	–	208	231	239	245	258	273	292	–	–	–
Green Bay, L. Michigan, Wisc. (Smith 1956)	TL											
	inches	–	8.1	10.4	10.7	11.0	12.9	–	–	–	–	–
	mm	–	206	264	272	279	328	–	–	–	–	–
	Wt (*oz*)	–	2.4	4.4	4.9	5.4	9.3	–	–	–	–	–
Marquette, L. Superior, Mich. (Dryer and Beil 1964)	TL											
	inches	–	12.6	12.7	12.8	12.7	13.6	–	–	–	–	–
	mm	–	320	323	325	323	345	–	–	–	–	–
Lake-of-the-Woods, Minn. (Carlander 1945)	SL											
	inches	4.2	6.3	8.2	9.7	10.8	11.6	12.6	13.2	15.0	15.8	–
	mm	106	161	207	246	275	295	319	336	380	402	–
L. Winnipeg, Man. (Keleher 1950)	SL											
	inches	–	–	8.1	9.1	9.8	10.6	11.5	12.1	12.8	13.9	–
	mm	–	–	206	230	249	270	291	308	325	353	–
L. Winnipeg, Man. (Keleher 1950)	SL											
	inches	–	–	–	9.1	9.9	10.3	10.5	–	–	–	–
	mm	–	–	–	230	252	262	267	–	–	–	–
		(identified as *C. nipigon*)										
Great Bear L., N.W.T. (Kennedy 1949b)	FL											
	inches	–	–	–	10.0	11.2	12.4	12.6	13.1	13.8	14.0	–
	mm	–	–	–	254	284	315	320	333	351	356	–
	Wt (*oz*)	–	–	–	8.0	9.0	13.0	14.0	16.0	18.0	18.0	–

until age 5 or 6 in Great Bear Lake. In inland lakes, weights of 0.5–1.5 pounds are common, in the Great Lakes 3–4-pound fish are uncommon, but this size is not unusual in the Prairie Provinces. The largest lake herring or tullibee recorded from Great Slave Lake weighed 5.5 pounds, was 22.5 inches (572 mm) long, and was caught in 1944. It is in the ROM collection, cat. no. 13498. The largest lake herring known to us was an 8 pound, 7-year-old female caught in central Lake Erie in 1949.

This is essentially a lake species, although it may occur in large rivers in the Hudson Bay region (Dymond 1933) and westward. It is a pelagic species, usually forming large schools in midwaters but its midwater depth varies with the seasons and the temperature. In Lake Superior, Dryer (1966) found it to have an all-season depth range of 60–174 feet (13–53 m). In general, there is a movement in spring and early summer from shallow to deep water, when lake herring move below the thermocline. They remain in the cooler, deep water until late summer, rising to just below the thermocline. As the upper waters cool, they move into shallower water (Fry 1937). The habit of moving into deeper water during summer may lead to mass mortalities if the hypolimnion becomes depleted of oxygen (McCrimmon 1952). The temperature tolerance of young ciscoes was investigated by Edsall and Colby (1970) who determined an upper lethal temperature of 78.8° F (26° C). Exploited cisco populations often exhibit wide fluctuations in numbers, sex ratios, and other features. A recent study by Clady (1967) reviewed such a population in Birch Lake, Mich. *See* also Carlander (1945), Scott (1951), and Smith (1956).

In keeping with its pelagic habitat, the lake herring is basically a plankton feeder but consumes a wide variety of foods. Larval ciscoes require light to feed and experimental evidence indicates that they begin to feed the day they hatch, while still carrying the yolk sac; dead zooplankton (*Cyclops*) are eaten at first (John and Hasler 1956). Studies of larval ciscoes in Lake Ontario by Pritchard (1930) indicated, however, that feeding commenced when about 10 days old, the food consisting of algae, copepods, and Cladocera. A detailed food study in Lake Nipissing (Langford 1938) showed that *Daphnia* and mayfly nymphs were important foods of adults in shallow water while *Diaptomus oregonensis* was the principal food in deep water. In the Great Lakes the crustaceans *Mysis* and *Pontoporeia*, copepods, and immature stages of aquatic insect groups, such as mayflies and caddisflies, were important adult food items (Pritchard 1931; Dryer and Beil 1964). Even flying ants, apparently eaten at the surface, were reported for Lake Huron specimens by Koelz (1929). In northern Saskatchewan, zooplankton, *Mysis*, midge and mayfly larvae, and water mites were important food items (Koshinsky 1965). But, food varies with the seasons and food studies conducted during spawning indicated that lake herring also eat their own eggs; they will also eat eggs of other species. Pritchard (1931) reported an average of 275 whitefish fry per stomach for lake herring feeding near a Lake Ontario hatchery outflow. And, on occasion, they will eat small minnows; indeed salted and live minnows are used as bait in winter angling through the ice.

In many respects, the lake herring is to aquatic predators what the rabbit is to its terrestrial counterparts, and forms part of the diet of a large number of fishes. The primary predator (except for man) is the lake trout, for which the lake herring is a preferred food.

It is also a common food of rainbow trout (Lake Simcoe), northern pike, burbot, yellow perch, and walleyes, when these species are present.

Bangham and Hunter (1939) examined 78 specimens of *C. artedii* from Lake Erie and found 30 fish parasitized. The cestode *Proteocephalus exiguus* was the dominant parasite, infecting 26 fish; cestodes *P. wickliffi* and *Abothrium crassum* were also present. One fish from the west end of the lake contained the nematode *Cystidicola stigmatura*.

Bangham (1941) found 15 of the 16 ciscoes taken from the deeper water of Proulx Lake in Algonquin Park, Ont., to contain parasites. He found the gill copepod *Ergasilus caeruleus* in large numbers. The immature stage of the cestode *Proteocephalus laruei* was present in four of the fish examined.

All 79 fish examined from Lake Huron waters by Bangham (1955) were infected. Parasites included 5 species of cestodes: *Proteocephalus laruei*, found in 71 fish; *Triaenophorus crassus* in 61 fish; *Diphyllobothrium* sp. in 54 specimens; and *P. exiguus* and *Abothrium crassum*. Other parasites identified were 2 species of nematodes (*Philometra* sp. and *Cystidicola stigmatura*), 2 of trematodes (*Diplostomulum* sp. and *Discocotyle salmonis*), 3 of copepods (*Salmincola inermis*, *S. wisconsinensis*, and *Argulus* sp.), 1 acanthocephalan (*Echinorhynchus salmonis*), and protozoan Myxosporidia.

Two hundred specimens of *C. artedii* from Lake Superior were examined for parasites by Warren (1951) who later described the occurrence of *Diphyllobothrium oblongatum* cysts in the flesh and demonstrated that they would develop to adult worms in herring gulls (Warren 1952).

C. artedii was described as a new host for the cestode *Cyathocephalus truncatus* in North America from specimens removed from the pyloric caeca of ciscoes caught in South Bay, Lake Huron (Dechtiar and Loftus 1965).

Hoffman (1967) listed trematodes (6), cestodes (10), nematodes (4), acanthocephalans (5), and crustaceans (7), parasites of *C. artedii* in North American waters.

In Lac la Biche, Alta., Paetz and Nelson (1970) attributed mass mortalities of this species, in part, to heavy gill infection by the copepod parasite *Ergasilus*.

The nutritive value of *C. artedii* was investigated by Klocke et al. (1947) who noted that lake herring (and burbot) could make a valuable contribution to the thiamine content of the American diet.

Relation to man The total value of this species to the Canadian economy would be exceedingly difficult to assess. Ecologically, it is of considerable importance for it is one of the main foods of the lake trout and may, at times, be important in the diet of other predaceous fishes. It is caught commercially by gillnets, but sometimes trapnets or seines are used. The Lake Erie fishery commonly used a floated (or canned) gillnet, thus catching the lake herring in its midwater habitat. Commercially caught ciscoes may be sold for the smoked fish trade, or as fresh or frozen fish, depending upon the fatness of the flesh. The flesh is usually of excellent flavour. It is also caught by sportsmen using spears, artificial lures, or live bait, and in the smaller lakes of the Great Lakes region may provide considerable sport for fly fishermen in the spring and a supplementary species for ice fishermen in winter.

In the Great Lakes, its abundance was described as unbelievable by numerous observers during the last century. For example, in 1868 the fishery overseer said that at Burlington Beach, Lake Ontario, "herring (alone which) frequent the bay in the month of November to spawn in unprecedented numbers of millions" (*see* Pritchard 1931). In the early 1900's the total yield of ciscoes from Lake Erie alone fluctuated around 20 million pounds annually, and in 1918 was over 48 million pounds. This fishery collapsed completely but as late as the 1950's approximately 20 million pounds were landed annually from the whole of the Great Lakes.

In northern Ontario and the western provinces, it is usually called tullibee, and may support a number of domestic fisheries for local consumption and as a food source for fur farms. It also supported extensive fisheries in Lake Winnipeg and other large lakes in Manitoba where important "tullibee" fisheries have been carried on for many years. Sometimes small local fisheries are conducted most efficiently only during the fall spawning runs.

In many parts of northern Canada it was an important winter food for native peoples and their dogs. Richardson (1836) remarked upon the fall fishery for ciscoes on Great Bear Lake and McPhail and Lindsey (1970) noted that a "herring" fishery was still in operation at Fort Franklin.

The lake herring was found to be a valuable source of thiamine by Klocke et al. (1947).

Nomenclature

Coregonus Artedi	— Le Sueur 1818a: 231 (type locality L. Erie (at Buffalo) and Niagara R. (at Lewiston))
Coregonus albus	— Le Sueur 1818a: 232
Salmo (Coregonus) tullibee (Richardson)	— Richardson 1836: 201
Salmo (Coregonus) Artedi (LeSueur)	— Richardson 1836: 203
Salmo (Coregonus) harengus (Richardson)	— Richardson 1836: 210
Coregonus clupeiformis DeKay	— Agassiz 1850: 339
Argyrosomus artedi (LeSueur)	— Evermann and Smith 1896: 305
Argyrosomus tullibee	— Evermann and Smith 1896: 320
Argyrosomus eriensis	— Jordan and Evermann 1909: 165
Argyrosomus huronius	— Jordan and Evermann 1909: 167
Leucichthys harengus (Richardson)	— Jordan and Evermann 1911: 6
Leucichthys sisco (Jordan)	— Jordan and Evermann 1911: 10
Leucichthys ontariensis	— Jordan and Evermann 1911: 13
Leucichthys artedi (LeSueur)	— Jordan and Evermann 1911: 17
Leucichthys eriensis (Jordan & Evermann)	— Jordan and Evermann 1911: 20
Leucichthys supernas	— Jordan and Evermann 1911: 22
Leucichthys manitoulinus	— Jordan and Evermann 1911: 31
Leucichthys tullibee (Richardson)	— Jordan and Evermann 1911: 32
Leucichthys macropterus	— Bean 1916: 25 (*see* Smith 1964)
Leucichthys nipigon	— Koelz 1925: 1
Leucichthys nueltinensis new species	— Fowler 1948: 142
Leucichthys churchillensis new species	— Fowler 1948: 144
Coregonus artedii LeSueur	— Scott 1967: 29

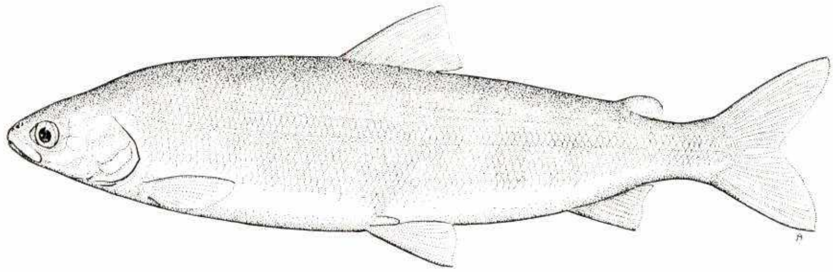
Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *artedii* — after Petrus Artedi, the "Father of Ichthyology," associate of Linnaeus and perhaps the ablest systematic zoologist of the 18th century.

Common names Cisco, lake herring, tullibee, freshwater herring, ciscoe, blueback, sand herring, shallowwater cisco, grayback tullibee, common cisco, Bear Lake herring, blueback tullibee, herring-salmon. French common name: *cisco de lac.*

The name tullibee is apparently derived from the name "ottonneebees" which Sir John Richardson (1836) attributed to the Cree Indians; he attributed the name tullibee to the fur traders.

ARCTIC CISCO

Coregonus autumnalis (Pallas)



Description Body elongate, length to about 12–15 inches (305–381 mm), less compressed laterally than most ciscoes, greatest body depth in front of dorsal fin, 20–23% of total length. Head moderate 22–24% of total length; eye moderate, its diameter 20–24% of head length; snout length usually slightly greater than eye diameter; mouth moderate, terminal, upper and lower jaws about equal, maxillary extending posteriorly to below anterior half of eye; a small cluster of teeth on tongue. Gill rakers, total count 41–48 (gill rakers on lower limb 26–30), longer than on *C. laurettae*, and slender. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, rays 10–12; caudal distinctly forked; anal rays 12–14; pelvic rays 11 or 12, a distinct pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large, 82–110 in lateral line. Pyloric caeca 113–183. Vertebrae 64–67.

Nuptial tubercles developed on scales on flanks of males.

(*See also* McPhail 1966; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; usually brown or green on the back, becoming silvery on sides and below. Anal and pelvic fins immaculate, pectoral fins lightly pigmented on upper surface; remaining fins lightly pigmented and dusky.

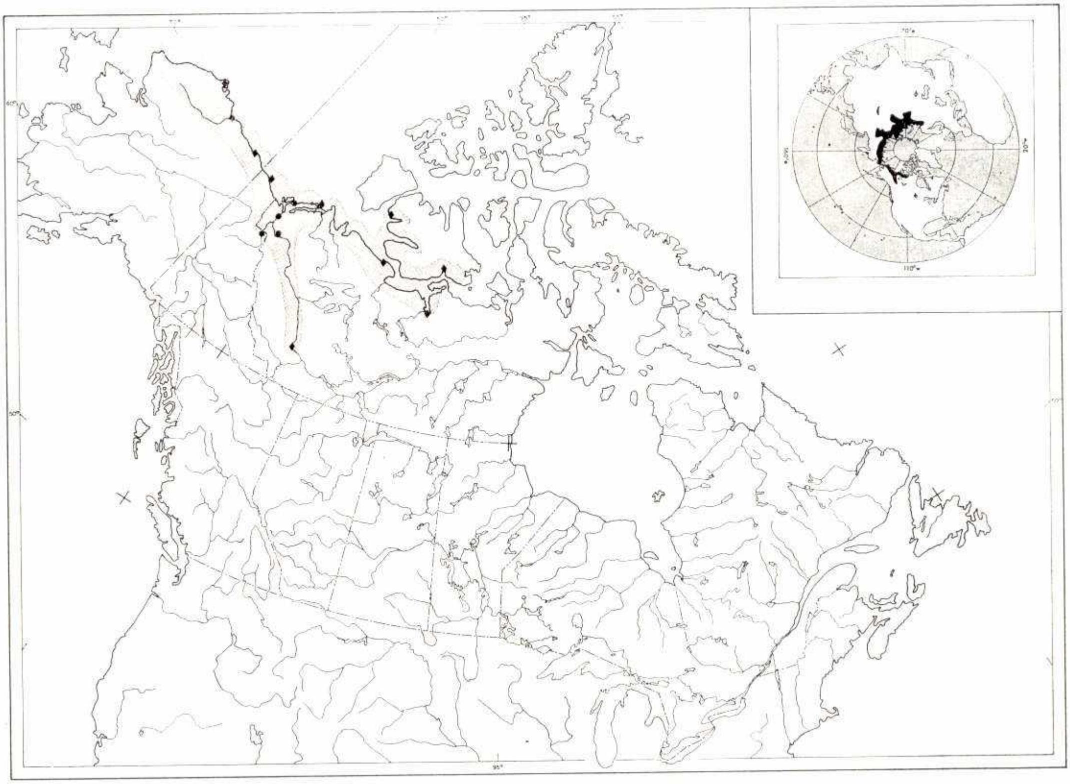
Systematic notes The species was described by Pallas (1776) as *Salmo autumnalis*, based on specimens from the Kara River, Siberia. North American populations are not distinguished taxonomically from those in Siberia. In North America, the arctic cisco has often been confused with *C. laurettae* and less frequently with *C. tullibee* (= *artedii*), hence, the literature must be treated with caution. *See C. laurettae* for further information and *also* McPhail (1966) and McPhail and Lindsey (1970).

Distribution The arctic cisco occurs in the coastal waters and lower parts of arctic rivers in Europe, Asia, and North America, from the White Sea region west to Alaska and the Northwest Territories.

In North America it occurs in the Arctic Ocean drainages from Point Barrow, Alaska, east along the arctic coastal waters and tributary rivers to Mackenzie delta, Cape Bathurst, Bathurst Inlet, and Cambridge Bay.

Biology The biology of the arctic cisco has received little or no study in northern Canada but the biology of Siberian populations is rather well known. It is an anadromous species. An upstream spawning migration takes place in summer in Siberia, usually beginning in July.

Spawning takes place over gravel beds, often in swiftly flowing water. Like all whitefishes the eggs are broadcast and abandoned by the parents. The egg number of Yenisei River fish was given by Nikol'skii (1954) as 7700–41,300. McPhail and Lindsey noted



that large females may carry 90,000 eggs. Adults apparently do not spawn every year in Siberian waters, and probably not in ours either. After spawning, the adults again move down river to the sea. On the Mackenzie River, Wynne-Edwards (1952) noted that it was "caught at Aklavik between freeze-up and Christmas presumably on its way out to sea, and ascending again in the early spring." The eggs presumably hatch in the spring and the young descend to the estuaries, as in Siberia. Maturity is attained in 5–7 years in some Siberian rivers, 9–10 in others, but no rate-of-growth studies have been made in Canada. Dymond (1943) said the arctic cisco attained a length of 12–18 inches (305–457 mm) and a weight of 3 pounds in Canada, but weights to $5\frac{1}{2}$ pounds are reported from Siberian waters.

The arctic cisco behaves like a typical anadromous species, leaving the sea or estuarial waters in spring and summer, ascending freshwater rivers to spawn, and then moving down to the sea again. Although other whitefishes may also move into salt water, such as the lake herring and lake whitefish in Hudson Bay, none seem to spend more time at sea than the arctic cisco, although admittedly the waters it frequents are less saline than those off the Atlantic or Pacific coasts.

In Siberia, the food consists mainly of crustaceans, such as *Mysis* and *Pontoporeia*, and small fishes, such as young sculpins, smelt, and whitefish.

Lawler (1970) listed those parasites attacking *C. autumnalis* in waters of the USSR as compiled by Bykovskaya-Pavlovskaya et al. (1962) and discussed their effect. Information on parasites in North American arctic ciscoes is lacking.

Relation to man The arctic cisco is a common and valuable food fish throughout its range. In Siberia it is an important commercial species and is usually fished during its summer migration in rivers. It was also regarded as a valuable food fish in the lower Mackenzie River, according to Dymond (1943), who noted that it was well liked as human food and equal to whitefish as dog food, and that at Arctic Red River, it was caught, dried, and smoked in great numbers every summer by the Indians. Wynne-Edwards (1952) noted that it formed the principal object of a summer fishery at The Ramparts on the Mackenzie.

Nomenclature

Salmo (Coregonus) autumnalis	— Pallas 1776: 32 (type locality Pechor and Enissei rivers of western Siberia)
Leucichthys autumnalis (Pallas)	— Dymond 1943: 228
Coregonus autumnalis (Pallas)	— Walters 1955: 279
	— McPhail 1966: 146

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *autumnalis* — of the autumn.

Common names Arctic cisco, salmon-herring. French common name: *cisco arctique*.

BLOATER

Coregonus hoyi (Gill)

Description Body elongate, average total length about 8–10 inches (203–254 mm) or greater, depending on lake, distinctly compressed laterally and thin, greatest body depth in front of dorsal fin, 17–24% of body length. Head long, 23–27% of total length; eye small, its diameter 22.8–26.4% of head; snout length greater than eye diameter, usually rather short or pointed; mouth terminal, lower jaw usually protruding beyond upper and with a distinct tubercle at the tip, maxillary extending posteriorly to below the anterior half of eye. Gill rakers total count 38–50 (Lake Ontario), 37–48 (Lake Michigan), 37–47 (Lake Huron), 37–49 (Lake Superior), 40–48 (Lake Nipigon). Branchiostegal rays 8 or 9 (Lake Superior). Fins: small dorsal adipose present, all rayed fins are long; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 11 or 12; pelvic rays 11; pectoral rays 15 or 16. Scales cycloid, large, 63–84 in lateral line. Vertebrae 55–57.

Nuptial tubercles developed on scales on sides of males and at least some females.

(*See also* Dymond 1926; Koelz 1929; Pritchard 1931.)

Colour Overall colouration silvery with some pink or purple iridescence and a greenish tinge above the lateral line. Ventral surface silvery white. Weak pigmentation on head including cheeks and tip of lower jaw. Fins usually weakly pigmented, although dorsal and caudal fins dark edged; pelvics usually immaculate.

Systematic notes This is the smallest of the endemic deepwater ciscoes. It was named, but not described, by Gill (*in* Hoy 1872) in honour of Dr P. R. Hoy who had sent him the specimen. *See* Koelz (1929, p. 312) for additional details. Koelz (1929) selected a lectotype, a mutilated specimen 5.4 inches (137 mm) long, probably collected in Lake Michigan, off Racine, Wis., in March 1872, by Hoy. This specimen, and a cotype, both in poor condition, are stored in the United States National Museum, cat. no. 8902.

The populations differed slightly in meristic and morphometric values from lake to lake, but not sufficiently to warrant taxonomic recognition. The changes in population structure in most of the Great Lakes have resulted in morphological changes in some lakes, especially Lake Michigan.

Distribution *Coregonus hoyi* has generally been considered endemic in the Great Lakes basin where it occurs in all lakes, including Lake Nipigon, except Lake Erie. There is also a report of a single specimen, identified as this species, from Eva Lake, Rainy River District, Ont., (Lindeborg 1941). But, since the record is based on a single specimen only 3.0 inches (76 mm) long, more material should be examined and the identity confirmed.

Biology Spawning generally takes place in February and March for all lakes covered by observations, but many observers remarked that some spawning must occur throughout the year (Jobes 1949b; Dryer and Beil 1968). In almost every month of the year a few ripe, nearly ripe, or spent males and females have been caught. They apparently spawn over almost all bottom types in depths from about 120 to 300 feet (36–91 m).

Information on number and size of eggs was provided for Lake Superior by Dryer and Beil (1968), based upon samples collected during 1964–1965. Study of 20 females ranging in average length from 8.4 inches (213 mm) to 11.7 inches (297 mm), yielded a range in total number of eggs from 3116 to 12,045. The larger females had the greater number of eggs, but the average number of eggs per ounce of fish was 1241. Over the whole size-range studied, the number of eggs per ounce of fish showed little variation. Bloaters produced about 60% more eggs than *C. artedii* of the same size. These data should not be interpreted as representative of the pre-1950 *hoyi* populations in the Great Lakes when the growth rates and maximum size attained were less than during the period of Dryer and Beil's study.

The eggs are relatively large, with an average diameter of 1.95 mm, based upon examination of 160 eggs from eight females. These figures for egg diameter, given by Dryer and Beil, presumably referred to eggs removed directly from the ovary of the female, not to eggs released into the water, with subsequent uptake of water and increase in diameter.

Studies of embryological development and larval descriptions have apparently not been published, but much information on larval bloaters in Lake Michigan was given by Wells (1966). Collections of larval *hoyi* were made with special nets, from April through August, 1964. Although the total lengths of the larvae ranged from 8.6–14.9 mm, the average length of the samples taken throughout the period remained remarkably uniform, ranging from 11.0–11.3 mm. Wells concluded that the unchanging size composition and small size of the larvae suggested that the sampling followed closely the progress of hatching, that the method was selectively sampling the 10–12 mm size-range, and that larger larvae evaded capture. Even so, it was the first successful attempt to study the free larval stages of any Great Lakes endemic deepwater cisco and was possible only because *C. hoyi* was practically the only deepwater cisco remaining in Lake Michigan. Despite the number of larvae collected information on larval growth was not available because of the selective nature of the sampling and the difficulty of capturing larger larvae.

The bloater was traditionally the smallest and had the slowest growth rate of any of the endemic deepwater ciscoes, but the growth rate varied from lake to lake. The average total length in Lake Michigan was about 8 inches (203 mm) according to Smith (1964a), and in Lake Ontario (south shore) was about 10 inches (254 mm), (Stone 1947). But, it was only in these two lakes that it grew regularly over 8 inches (203 mm) long, and hence supported a commercial fishery (Koelz 1929).

Growth studies of larger bloaters have been conducted for Lake Ontario (Stone 1947), Lake Michigan (Jobes 1949b), and Lake Superior (Dryer and Beil 1968). The earlier studies reflected the situation prior to the tremendous changes in growth rate and body form that followed the disappearance of lake trout and larger coregonine fishes, while the Lake Superior study demonstrated the changes evident even in the post-1950 period. (*See* table below.)

Females usually lived longer and attained a larger size than males, but the latter usually matured earlier. In Lake Ontario, females lived to age 10 or 11 while males lived only to age 9 (Stone 1947). In Lake Superior, Dryer and Beil (1968) noted that for populations of the 1958–1965 period, some males attained age 10, females age 11. The commercial catch was usually dominated by age 6 fish during the same period.

Considerable attention has been directed to the apparent predominance of females among bloater populations in Lake Michigan in recent years. Brown (1970) summarized the existing data and showed that the percentage of females increased from 72% of fish sampled in 1928–1932 to 95% in 1963 and 94–97% during the period 1964–1969. Brown suggested that the many biological changes evident in Lake Michigan populations (size, growth rate, sex ratio plus morphometric changes may have indicated the beginning of a serious population decline. It is perhaps significant that Stone (1947) noted that the percentage of females in Lake Ontario in 1942 was 81.9%. Dryer and Beil (1968) also remarked upon this phenomenon and listed the Great Lakes coregonines for which it had been reported. No explanations of the mechanisms involved have been advanced for coregonines, but it is interesting that sea lamprey populations in the upper Great Lakes also exhibited considerable variation in sex ratios during the period of population expansion and subsequent habitat saturation. *See* Applegate and Thomas (1965) for further information.

The bloater lives in shallower water than the other deepwater ciscoes. Koelz (1929) reported that in Lake Michigan it was occasionally caught in poundnets at depths as shallow as 30 feet, but this seldom occurred in Canadian waters. In Lake Ontario, Pritchard noted that it ranged at all depths from 125 to 400 feet (38–121 m) and reached maximum abundance at 250–300 feet (76–91 m). In Lake Nipigon, Dymond (1926) considered it to have the most limited vertical range of any cisco in the lake, since it was restricted to depths of 90–330 feet (27–100 m).

Information for the other Great Lakes is more or less in agreement. It was generally considered rare or uncommon beyond 420

		Age (*years*)										
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
L. Ontario	FL											
(Pritchard	*inches*	6.1	6.9	8.2	9.1	9.7	11.1	–	–	–	–	–
1931)	*mm*	155	175	208	231	246	282	–	–	–	–	–
	Wt (*oz*)	1.1	1.8	3.1	4.1	4.9	7.7	–	–	–	–	–
L. Ontario	TL											
(Stone 1947)	*inches*	–	–	8.3	8.7	9.3	9.8	10.1	10.6	11.1	11.4	12.4
	mm	–	–	210	221	237	249	256	268	287	291	315
L. Michigan	TL (*inches*)											
(Jobes 1949b)	M	–	7.0	7.4	8.4	9.1	9.8	10.6	–	–	–	–
	F	–	6.9	7.6	8.4	10.0	10.1	10.9	–	–	–	–
	TL (*mm*)											
	M	–	178	188	213	231	249	269	–	–	–	–
	F	–	175	193	213	254	257	277	–	–	–	–

feet (128.0 m) but reached a maximum depth of about 600 feet (183.0 m) in the deep upper lakes. In Lake Michigan, Jobes (1949b) found maximum abundance to occur at about 120–350 feet (36.6–108.0 m).

Recently, Wells (1966) provided unique and valuable information on larval bathymetric distribution for Lake Michigan. The larvae occurred over a wide depth range, usually near bottom. About 83% of all larvae were caught at depths between 240 and 360 feet (73.2–109.7 m) but were most abundant between 300 and 360 feet (91.4–109.7 m). About 96% were taken at levels at which the maximum temperature did not exceed 40.5° F (4.7° C).

The food consists mainly of *Mysis relicta* and *Pontoporeia affinis*. Pritchard (1931) examined 58 bloater stomachs from Lake Ontario and indicated that these two organisms, with the addition of copepods and small molluscs, constituted the main food. But the most complete recent report was a quantitative study by Wells and Beeton (1963) for Lake Michigan bloaters. These authors examined nearly 2000 stomachs. Fish under 7 inches (178 mm) long ate mainly zooplankton, especially *Cyclops bicuspidatus* and *Diaptomus* spp., and only a few (less than 10%) *Pontoporeia* and *Diaptomus* spp. But, as the fish became larger they consumed more *Pontoporeia* and *Mysis*. The amphipod *Pontoporeia* was, on the whole, the more important of the two, having an average percentage occurrence of 60.7, that for *Mysis* being 48.2. It was more important in shallower waters, down to about 160 feet or 49.4 m but below this depth, *Mysis* became increasingly important. *Pontoporeia* lives primarily on bottom, *Mysis* just off bottom by about 3 feet (0.9 m) hence, it would seem that large *hoyi* fed on or near the bottom in Lake Michigan.

In contrast to the Lake Michigan study, Dryer and Beil (1968) concluded that in Lake Superior *C. hoyi* was primarily a pelagic feeder. The order of frequency of food items in over 300 stomachs was copepods, *Mysis* and *Pontoporeia*, the order by volume was *Mysis*, copepods, and *Pontoporeia*. Fish eggs and fingernail clams were also eaten, and the authors considered these to be evidence of occasional bottom feeding although fish eggs seemed to be a regular part of the diet. At depths of 260–360 feet (79–110 m) 5 of 9 stomachs contained fish eggs, to a maximum of 130 in one stomach.

The major natural predator on the bloater was probably the lake trout, before the trout's decimation by the sea lamprey. The total consumption of bloaters by lake trout must have been enormous. For example, Hile and Buettner (1955) estimated that at least 30 million pounds of bloaters were eaten annually by lake trout in Lake Michigan to support a yearly commercial yield of 6 million pounds of trout. Bloaters were also eaten by burbot (Van Oosten and Deason 1938) but to a much lesser extent.

The bloater was considered by Pritchard (1931) to be one of the most heavily parasitized of Lake Ontario ciscoes. He recorded bothriocephalid larvae (tapeworms), the nematode *Cystidicola* sp. (in 40% of specimens) and the copepod *Salmincola inermis* (about 20% of specimens).

Bangham (1955) examined 47 specimens of *C. hoyi* from Lake Huron and found all infected. Parasites included trematodes *Diplostomulum* sp., in 24, and *Discocotyle salmonis* in 5, cestodes *Diphyllobothrium* sp. in 26, *Proteocephalus exiguus* in 13, *P. laruei* in 32, and *Triaenophorus crassus* in 17, nematode *Cystidicola stigmatura* in 4, acanthocephalans *Echinorhynchus leidyi* in 4, and *E. salmonis* in 18, and the crustacean *Salmincola wisconsinensis* in one.

Hoffman (1967) added the cestode *Cyathocephalus americanus* and the leech *Piscicola milneri* to the list of parasites of this species in North American fresh waters.

Relation to man The bloater has never been a valued species in the Canadian commercial fishery on the Great Lakes, in contrast to its utilization in certain United States waters. The extent to which the bloater contributed to the Lake Huron chub fishery during the early 1960's is unknown, although it may have been significant. Practically the only chub fishery in Canadian waters of the

Great Lakes was that in Lake Huron. The figures tell an all too familiar story of declining yields. The following table for Lake Huron shows the landings (in pounds) of "chubs" *Coregonus* (*Leucichthys* spp.) exclusive of *Coregonus artedii*. The increasing poundage from Georgian Bay probably reflects a transfer of effort from the depleted Lake Huron stocks to the limited reserves in Georgian Bay.

Year	L. Huron (exclusive of Georgian Bay)	Georgian Bay	Total
1961	2,341,528	31,393	2,372,921
1962	2,180,123	81,515	2,261,638
1963	1,668,729	104,122	1,772,851
1964	1,442,020	120,654	1,562,674
1965	1,083,035	408,552	1,491,587
1966	652,614	285,503	938,117

In Lake Ontario, the bloater was not considered commercially important in Canadian waters (Pritchard 1931) although it constituted the bulk of the United States commercial catch of deepwater ciscoes (Stone 1947).

During the early years of the chub fishery throughout the Great Lakes, the bloater was spurned because of its small size, but it became increasingly important after 1950. This was particularly true in Lake Michigan where annual catches fluctuated between 5 and 12 million pounds during the 1960's. The catches declined in 1963 and 1964 as a result of botulism scare in 1963, according to Smith (1968). The reported outbreaks of botulism were attributed to improperly processed chubs, composed mainly of *Coregonus hoyi*. An improved process of smoking at a higher temperature eliminated the problem (Bratzler and Robinson 1967).

The bloater was also of great importance as a forage fish for the lake trout, as indicated under the *Biology* section.

Nomenclature

Argyrosomus hoyi	— Gill (*in* Hoy 1872: 99) (type locality Lake Michigan off Racine, Wis.)
Argyrosomus prognathus	— Evermann and Smith 1896: 314
Leucichthys hoyi Gill	— Hubbs 1926: 13
	— Koelz 1929: 449
Coregonus hoyi (Gill)	— Hubbs and Lagler 1958: 54
	— Scott 1967: 31

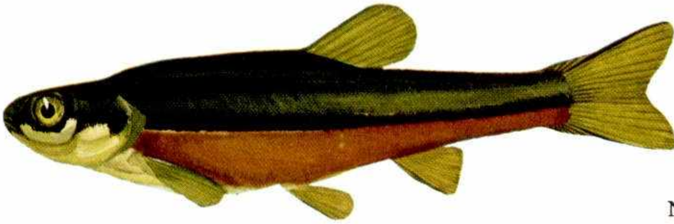
Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *hoyi* — after Dr P. R. Hoy of Racine, Wis., naturalist who collected fishes of Lake Michigan.

Common names Bloater, bloat, Hoy's cisco. French common name: *cisco de fumage*.

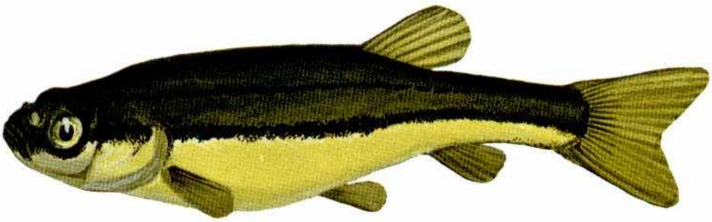
DEEPWATER CISCO

Coregonus johannae (Wagner)

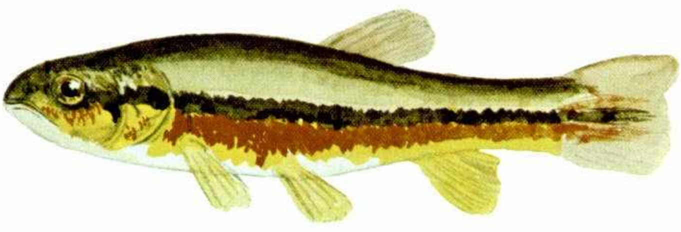
Description Body elongate, average total length about 11.4 inches (290 mm), moderately compressed laterally, greatest body depth in front of dorsal fin, about 22–27% of total length. Head relatively long, 22.8–26.4% of total length; eye moderate,



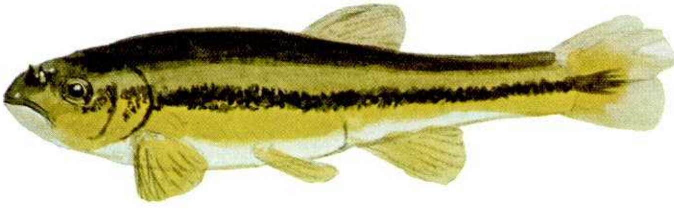
Northern redbelly dace



Northern redbelly dace



Finescale dace



Finescale dace

shorter than snout; snout narrow, elongate, 25–31% of head length; mouth terminal, lower jaw usually equal to upper jaw but may be longer or shorter; maxillary extending posteriorly to below anterior portion of eye but not reaching centre of eye. Gill rakers relatively long, 26–36 (Lake Michigan), 25–35 (Lake Huron), usually 10–12 on upper limb of the arch, 17–20 on lower limb. Branchiostegal rays 8 or 9 (Lake Huron). Fins: small dorsal adipose present; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 10–16; pelvic rays 11 or 12; pectoral rays 14–20 (Lake Michigan), 15–19 (Lake Huron). Scales cycloid, large, 74–95 in lateral line. Vertebrae 56–58.

Nuptial tubercles (pearl organs) developed on breeding males. (*See* Koelz 1929).

Colour Overall colouration silvery with pink or purple iridescence. Pale blue or green on the back, becoming blue-green on the sides. Ventral surface silvery white. Pigmentation on premaxillaries and on top of head. Fins mainly clear or white, translucent, with lightly scattered pigmentation, pelvics immaculate.

Systematic notes This deepwater species, the largest of the endemic ciscoes, was described by Wagner (1910). The holotype is a ripe male, 10.5 inches (265 mm) in length, caught in Lake Michigan, about 18 miles off Racine, Wis., on July 3, 1906. It is stored in the United States National Museum, cat. no. 87353. When examined in 1959, the specimen was in fair condition and when remeasured had a total length of 12.5 inches (315 mm).

The populations in Lake Huron apparently had fewer lateral line scales, more pectoral rays, longer head, longer snout, longer paired fins, and were more pigmented than those from Lake Michigan.

Distribution The deepwater cisco was indigenous to the Great Lakes basin and occurred only in the deeper portions of lakes Huron and Michigan. No specimens have been seen in Lake Michigan since 1951 (Moffett 1957) and, although it is rare in Lake Huron, its actual status is unknown.

Biology The reproductive or spawning phase of the life history of the deepwater cisco is most imperfectly known and, considering its extinction in Lake Michigan and rarity in Lake Huron, it is unlikely that our meagre knowledge will be expanded.

In Lake Huron, spawning apparently occurred between mid-August and the end of September, according to the observations available to Koelz (1929). He reported that females with well-developed eggs, and one with ripe eggs, were taken off Wiarton and Lion's Head, Georgian Bay, on July 28 and 30, 1919. Examination of other catches made in Georgian Bay and off Alpena, Mich., which included ripe or spent females and males with pearl organs, led to the conclusion that spawning commenced in August and ended before the last of September. Spawning grounds were never found. Koelz also considered the possibility that some females may have spawned every second year, a suggestion not applied to ciscoes in any other Great Lakes.

Information on other aspects of the life history of *johannae* is also meagre, and we know next to nothing of their fecundity, embryology, early life history, or rate of growth. Ages can be determined from scales and doubtless scale samples are filed away in government laboratories. Mature specimens smaller than 6.5 inches (165 mm) were not found, and most specimens 7.7 inches (195 mm) in length were mature (Koelz 1929).

This species was regarded as the largest of the endemic deepwater ciscoes and in Lake Michigan was said to average about 11.4 inches (290 mm) in length and to have a maximum weight of about 1.5 pounds. Among the Lake Michigan chubs, it was exceeded in size only by the blackfin cisco (*Coregonus nigripinnis*).

In Lake Huron, the limits of depth distribution for nonspawning fish were given as 96–600 feet (29.3–182.9 m), but this cisco was caught rarely at depths shallower than 210 feet (64.0 m), and maximum abundance occurred at 300–480 feet (91.4–146.3 m). The maximum depth range was not known and may have been greater than 600 feet (Koelz 1929).

The only information on food seems to be that provided by Koelz (1929) for Lake Huron fish. Of 34 stomachs examined, 80–100% of the food ingested consisted of *Mysis*, with small quantities of *Pontoporeia* and fingernail clams (*Pisidium*) making up most of the remainder. A few aquatic insects and fish scales were also observed, and about half of all specimens had ingested sand, cinders, and wood fragments.

The only parasites reported for the deepwater cisco were the larval form of the nematode *Dacnitoides cotylophora* and the crustacean *Achtheres corpulentus* (Hoffman 1967).

Relation to man This was the largest of the endemic deepwater ciscoes of the Great Lakes and one of the species preferred by the chub fishery; consequently, fishing pressure on it was intense. The final extinction of *johannae* from Lake Michigan is usually attributed to the combination of heavy commercial exploitation and predation by the sea lamprey during the 1940's. In any case, *johannae* has not been seen in Lake Michigan since 1957. Its status in Lake Huron is not known to us, but it is presumed to be rare.

Nomenclature

Argyrosomus johannae	— Wagner 1910: 957 (type locality Lake Michigan, off Racine, Wis.)
Argyrosomus hoyi	— Evermann and Smith 1896: 310
Leucichthys johannae (Wagner)	— Hubbs 1926: 13
Coregonus johannae (Wagner)	— Hubbs and Lagler 1958: 55
	— Scott 1967: 31

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *johannae* — after "life-companion" of George Wagner.

Common names Deepwater cisco, deepwater chub, the chub. French common name: *cisco de profondeur*.

KIYI

Coregonus kiyi (Koelz)

Description Body elongate, average total length about 10 inches (254 mm), distinctly compressed laterally, and thin, greatest body depth in front of dorsal fin 20–30% of body length. Head about 23–26% of total length; eye large, but shorter than snout, its diameter 22.2–26.4% of head length; snout always longer than eye; mouth terminal, lower jaw usually projecting beyond upper, usually with a distinct symphyseal knob or projection, maxillary pigmented and extending posteriorly to below the anterior half of eye. Gill rakers, total count 39–47 (Lake Ontario), or 34–45 (Lake Michigan). Branchiostegal rays 8 or 9 (Lake Superior, Koelz 1929). Fins: small dorsal adipose present, all rayed fins are long; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 9–16; pelvic rays 11 or 12, pelvic axillary scale present; pectoral rays 15–18. Scales cycloid, large, 71–91 in lateral line. Vertebrae 55–58.

Nuptial tubercles or pearl organs developed on breeding males.

The description of this species is based mainly on Lake Ontario specimens (Pritchard 1931); the anal ray count is from Lake Michigan specimens (Koelz 1929).

Colour Overall colouration silvery with pink or purple iridescence, dark on back, silvery on sides, and white below; often dark on tip of lower jaw, top of head, back, and on dorsal and caudal fins. Pelvics usually immaculate.

Systematic notes This deepwater form is endemic to the Great Lakes and was described by Koelz (1921). The holotype is a female, 7.5 inches (191 mm) in length to base of caudal fin, caught in Lake Michigan August 23, 1920, and stored in the United States National Museum, cat. no. 84100. Koelz (1929) assigned the Lake Ontario form to the subspecies *orientalis*, and assigned those in lakes Huron, Michigan, and Superior to the typical subspecies *C. kiyi kiyi*. The characters said by Koelz to distinguish the Lake Ontario subspecies were: higher number of gill rakers, shorter paired fins, and a shorter head. However, the distinctions are of little more than academic interest since the species has become exceedingly scarce, if not extinct, at least in lakes Ontario and Michigan.

Distribution The *kiyi* was indigenous to the Great Lakes basin and was limited in distribution to the deeper waters of lakes Ontario, Huron, Michigan, and Superior. It has been greatly reduced in numbers in most of these lakes and may even be absent. It is still present in Lake Superior.

Biology Some of the first investigations suggested considerable differences in time of spawning from lake to lake but gonads of individual deepwater ciscoes of many species may become prematurely ripe. This condition can be misleading, especially if only a few specimens are available.

This species has a rather prolonged spawning period that may extend from November to January. In Lake Ontario, spawning was reported to have commenced in late October, 1926, and to have continued as late as January 8, 1927. In Lake Superior, it takes place usually in November or December. In 1959, of kiyi caught between November 23 and December 6, 50% were ripe.

Spawning probably took place at depths of 300–550 feet (91.4–167.6 m) at temperatures ranging from 35.0°–38.0° F (1.7°–3.4° C). Data on fecundity, embryological development, and early life history are scarce or altogether wanting. Scale formation commenced at a total length between 27.2–32.2 mm (Hogman 1970).

Age analysis, using scales, indicated that growth was relatively slow. Lengths at ages from 1 to 8 for the former Lake Ontario and Lake Michigan populations are given below.

			Age (*years*)						
			2+	3+	4+	5+	6+	7+	8+
L. Ontario	FL *inches*		7.5	8.5	9.7	10.6	11.9	–	–
(Pritchard 1931)	*mm*		190	216	246	269	302	–	–
	Wt (*oz*)		2.9	4.4	5.9	7.3	10.7	–	–
L. Michigan	TL *inches*	M	9.9	9.7	10.1	10.4	10.5	10.1	11.4
(Deason and		F	10.1	10.1	10.4	10.7	10.9	11.2	10.6
Hile 1947)	*mm*	M	251	246	257	264	267	257	290
		F	257	257	264	272	277	284	269

The kiyi is one of the smallest of the chubs, averaging about 10 inches (254 mm) long and 6 ounces (170 g) in weight. At a given age, females were usually heavier than males. Females lived longer, to at least age 10, compared to 8 years for males, but the age attained varied slightly in different lakes.

This deepwater species was usually said to live at depths of 30–100 fathoms or 180–600 feet (54.9–182.9 m) but, in general, it occurred most frequently in depths over 300 feet. In Lake Ontario, Pritchard (1931) noted that kiyi seldom came into water less than 250 feet deep, and that it reached maximum abundance at about 410 feet. In Lake Superior, information gathered during 1958–1963 suggested that the species was abundant at about depths of 600 feet.

The crustacean *Mysis relicta* and the amphipod *Pontoporeia hoyi* were the most common food items of the Lake Ontario populations studied by Pritchard (1931), and *Mysis* was reported as the principal food of Lake Huron *kiyi* by Koelz (1929). *Mysis* was also considered to be an important food in Lake Michigan but constituted only 30.3% of ingested food, compared with *Pontoporeia*, which made up 69.7% (Bersamin 1958). As many as 202 *Mysis* were found in one kiyi stomach from Lake Michigan.

The nematode *Cystidicola* sp. was the only parasite reported from Lake Ontario by Pritchard (1931). Hoffman (1967) listed a crustacean, *Salmincola inermis*, and the larval form of the cestode *Diphyllobothrium* sp.

Relation to man The species was commercially important in Lake Ontario in the 1920's and 1930's, but no specimens have been reported for many years. It is possibly present in numbers in Lake Superior but has largely disappeared from Lake Michigan. Its status in Lake Huron is unknown. (*See also* p. 231.)

Nomenclature

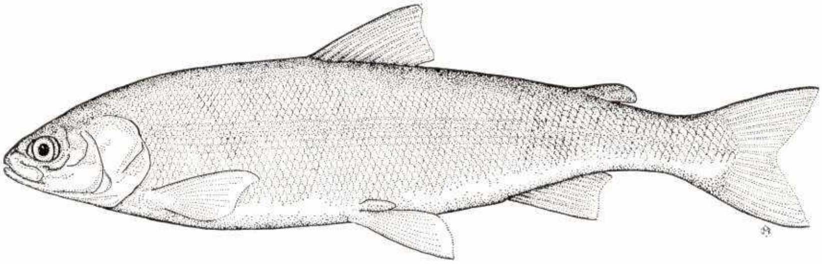
Leucichthys kiyi	— Koelz 1921: 1 (type locality 12 miles ExS of mouth of the Sturgeon Bay Ship Channel in Lake Michigan)
Coregonus kiyi (Koelz)	— Hubbs and Lagler 1958: 55
	— Scott 1967: 32

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *kiyi* — name used by "chub" fishermen of Lake Michigan.

Common names Kiyi, chub, waterbelly, mooneye. French common name: *cisco kiyi*.

BERING CISCO

Coregonus laurettae Bean



Description Body elongate, length to about 12 inches (305 mm), less compressed laterally than most ciscoes, greatest body depth in front of dorsal fin, about 20% of total length. Head moderate, 22–25% of total length; eye moderate, its diameter 20–25% of head length; snout length about equal to eye diameter; mouth moderate, terminal, upper and lower jaws about equal, maxillary broad, and long, extending posteriorly to below middle of eye; a small cluster of teeth on tongue. Gill rakers, total count 33–40 (gill rakers on lower limb 21–25), shorter than on *C. autumnalis*. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, rays 11–13; caudal distinctly forked; anal rays 12–14; pelvic rays 10–12, a distinct pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large 76–95 in lateral line. Pyloric caeca 71–123. Vertebrae 62–65.

Nuptial tubercles probably developed on males but no direct evidence.

(*See also* McPhail 1966; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; generally brown or green on the back, becoming silvery below. Anal, pelvic, and pectoral fins immaculate or nearly so; dorsal and caudal fins lightly pigmented and dusky.

Systematic notes The species was described by Bean (1882). No holotype was designated but the cotypes, four in number, (USNM cat. no. 27695) were collected at Point Barrow, Alaska, and an additional co-type (USNM cat. no. 27915) was collected at Port Clarence, Alaska. Many authors have regarded *C. laurettae* as a synonym of *C. autumnalis* (Dymond 1943; Walters 1955) but the validity of *laurettae* was recently established by McPhail (1966) using the gill rakers on the lower limb of the first gill arch as the primary character. *C. laurettae* had 21–25 gill rakers on the lower limb, *C. autumnalis* 26–30 rakers on the lower limb. On re-examination of the Point Barrow types, McPhail noted that two were *C. autumnalis* (*sensu latum*) and one was *laurettae*; he, therefore, selected the Port Clarence specimen (gill raker count 14 + 23) as the lectotype. The form *Argyrosomus alascanus*, described by Scofield (1899) was considered by Jordan and Evermann (1911) and Dymond (1943) as a synonym of *C. laurettae*, with which McPhail agreed. He also discussed the origin of *C. laurettae* and *C. autumnalis*, noting their morphological similarity and probable common ancestry.

Distribution Restricted to extreme northwestern North America but may occur in northeastern Siberia, although not reported. The Bering cisco is known only from Alaska, where it occurs along the coast and in rivers from Cook Inlet on the Pacific slope to near the mouth of the Colville River, Beaufort Sea. Conceivably, it may be found in the coastal waters of the Yukon Territory.

Biology As noted by McPhail and Lindsey (1970) little or nothing is known of the biology of this species. It is a coastal form and is probably anadromous. The above authors suggested that it probably ascends rivers in late summer, spawns in early autumn and, after spawning, moves downstream. There is no information on age, growth, or maximum size but most specimens are of the order of 10–13 inches (254–330 mm) in total length. The meagre available evidence indicated that food consisted of crustaceans.

Relation to man It is possibly a good food fish and may be used by local people but because of its relatively small size, is not caught regularly in the gillnets in common use.

Nomenclature

Coregonus laurettae	— Bean 1882: 156 (type locality Point Barrow, Alaska)
Argyrosomus laurettae (Bean)	— Jordan and Evermann 1896–1900: 471
Leucichthys alascanus (Scofield)	— Jordan and Evermann 1911: 16
Leucichthys laurettae (Bean)	— Jordan, Evermann, and Clark 1930: 62
Argyrosomus alascanus Scofield	— McPhail 1966: 146

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *laurettae* — named for Mrs Lauretta H. Bean.

Common names Bering cisco, lauretta, herring, freshwater herring, lake herring, tullibee. French common names: *cisco de l'Alaska, cisco du Bering.*

BLACKFIN CISCO

Coregonus nigripinnis (Gill)

Description Body elongate, average total length about 13 inches (330 mm) in upper Great Lakes, distinctly laterally compressed, and deep, maximum body depth in front of dorsal fin, 25–29% of total length, body width about half body depth. Head broadly triangular, 21.3–26.4% of total length; eye large, its diameter 21.8–25.0% of head length; snout blunt, its length usually greater than eye diameter, 24.4–28.6% of head length; mouth terminal, lower jaw usually projecting beyond upper, sometimes equal to upper jaw, maxillary pigmented, and extending posteriorly to below anterior edge of pupil. Gill rakers, total count 41–52 (Lake Michigan), 40–52 (Lake Huron), 36–48 (Lake Superior), 44–54 (Lake Nipigon), 41–54 (Lake Winnipeg). Branchiostegal rays 8–10 (Lake Michigan), 9 (Lake Superior). Fins: small dorsal adipose present, all rayed fins rather long; dorsal 1, rays 9–11; caudal widely spread and deeply forked; anal rays 10–13; pelvic rays 11 or 12, pelvic axillary scale present; pectoral rays 15–18. Scales cycloid, large, 74–89 in lateral line. Vertebrae 56–59.

Nuptial tubercles or pearl organs developed on breeding males and on some females.

This description is based primarily on Koelz' (1929) description of *nigripinnis* from

Lake Michigan, the type locality, although it is now extinct there.

(*See also* Koelz 1929; Dymond 1926; Dymond and Pritchard 1930.)

Colour Overall colouration dark silvery, with pink or purple iridescence on the sides, back dark green to black and silvery below. Maxillary and mandible whitish but heavily pigmented. All fins typically black, particularly on outer half. The species is usually characterized by darkly pigmented fins and the deep body. *See* colour illustration facing p. 90.

Systematic notes The blackfin cisco was named by Gill (*in* Hoy 1872) from a specimen caught in Lake Michigan and sent to him by P. R. Hoy. The type was not extant according to Koelz (1929). The variability of *nigripinnis* in the Great Lakes convinced Koelz of the need to recognize four subspecies, as follows:

Coregonus nigripinnis nigripinnis (Gill)
— Lake Michigan
— Lake Huron
Coregonus nigripinnis regalis (Koelz)
— Lake Nipigon
Coregonus nigripinnis cyanopterus (Jordan and Evermann)
— Lake Superior
Coregonus nigripinnis prognathus Smith
— Lake Ontario

The Lake Ontario subspecies, *C. n. prognathus*, was erected on the basis of a single specimen which is stored in the United States National Museum (*Coregonus prognathus* Smith, cat. no. 45568). When examined in 1959, it was in good condition but had been eviscerated and the gill arch had been damaged. We were able to count 42 gill rakers (15 + 27) but the end of the upper arch was missing and presumably the complete count would be greater than 42.

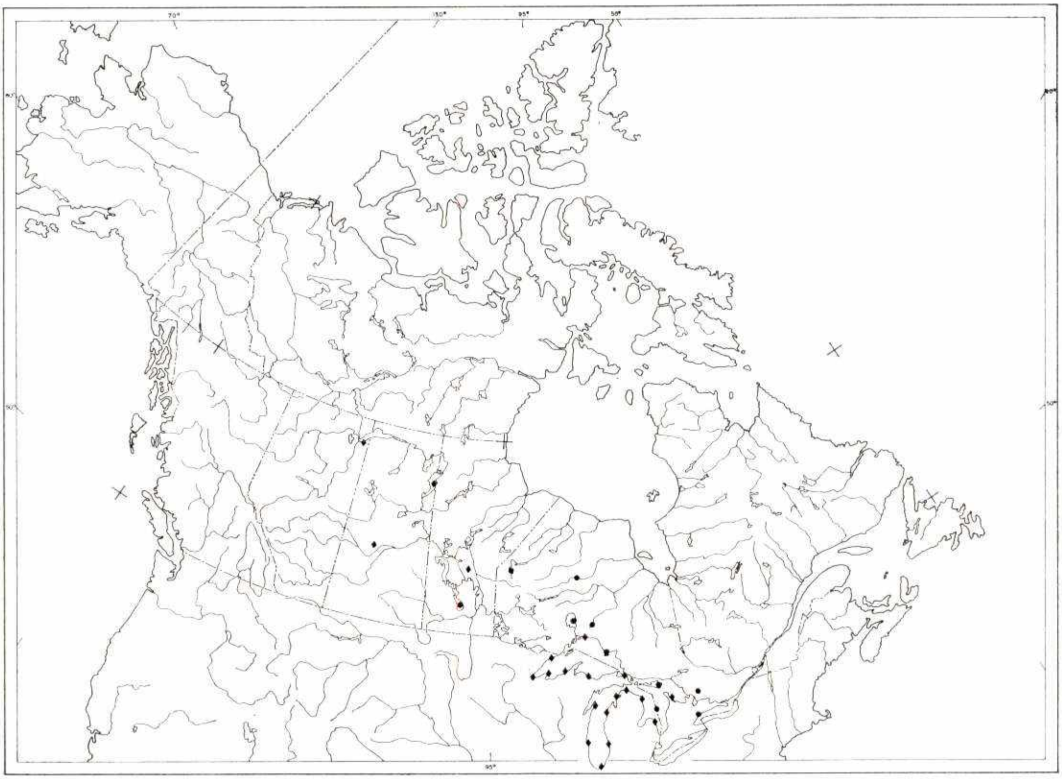
All Great Lakes populations, except those in Lake Nipigon, have become extinct, or nearly so, and hence, additional studies of the species will have to be conducted in inland waters. The validity of *nigripinnis* as a distinct species in many inland lakes is questionable. Even in Lake Huron, the similarity between *kiyi* and *nigripinnis* was so striking that Koelz (1929, p. 423) noted "small *nigripinnis* can be distinguished from *kiyi* probably only by the usual absence of black on the ventrals and the lighter pigmentation of the other ventral fins and by the fewer gill rakers, which in the former are (40)46–50(52) and in the latter (34)36–40(44), with 24 per cent more than 39." In Lake Superior, *nigripinnis* was less pigmented and most specimens had immaculate pelvic fins. The range in gill raker counts for Lake Superior *kiyi* was 36–45, and for *nigripinnis* 36–48, suggesting that differentiation of small *nigripinnis* from *kiyi* must have been difficult indeed.

Although *kiyi* does not occur in inland waters, *Coregonus artedii* does and it is often difficult to distinguish *nigripinnis* from *artedii*. Koelz remarked upon the similarity of *artedii* and *nigripinnis* in Lake Superior and compared the two species in such characters as the numbers of gill rakers and lateral line scales, and a variety of body measurements. He demonstrated that the two species could be distinguished in Lake Superior with a high degree of reliability. However, the same characters that would separate the two species in Lake Superior showed much greater overlap in Lake Nipigon and were, thus, much less effective. Compare, for example, gill raker counts:

	L. Superior	L. Nipigon
C. artedii	38–53	41–53
C. nigripinnis	36–48	44–54

Most coregonine fishes caught in inland lakes in northern Ontario and elsewhere in northern Canada tend to have darker fins and to be darker overall than the same species in the Great Lakes. *Coregonus artedii* with dark fins from inland lakes might easily be identified as *nigripinnis*.

The suspicion that *artedii* populations in inland lakes may have been identified as *nigripinnis* received support recently in an investigation of the ciscoes of Lake Waskesiu, Sask., by Kooyman (1970). Both *nigripinnis* and *artedii* (= *tullibee*) were reported to occur in the lake (Dymond and Pritchard 1930; Dymond 1943) but on re-examination only one species group, *Coregonus artedii*,



could be identified, although there were two distinct spawning groups, which differed markedly in age composition.

Coregonus nigripinnis is a problem species in inland waters and is most decidedly in need of critical systematic review. It may well prove to be taxonomically inseparable from a broadly redefined *Coregonus artedii*.

Distribution The blackfin cisco once ranged through all the Great Lakes except Lake Erie, but has now entirely disappeared from lakes Ontario and Michigan and there are no recent records from lakes Huron or Superior. It has been reported from a number of inland lakes in Ontario and Manitoba. Dymond (1943) considered this species to occur also in such Saskatchewan lakes as Waskesiu, Little Trout, Burntwood, and Heart, and from Lake Athabasca in Alberta. However, its occurrence in Saskatchewan and Alberta has not been confirmed by recent studies (Kooyman 1970).

Biology Information on time and place of spawning of Great Lakes stocks is indefinite. In Lake Superior, Koelz (1929) reported that "Pearled males and females spent, spawning, or nearly ripe were collected out of Grand Marais, Mich., on October 3, 1917, in 65 fathoms and deeper (record 2) and out of Rossport, Ont., on October 4, 1921, in 80 to 90 fathoms." Conclusive decisions on time of spawning in the other Great Lakes cannot be made but the available evidence suggests that it took place late November to January, possibly over a clay bottom.

There appears to be no data available on fecundity, embryological development, or early life history.

No age and growth studies are available for Great Lakes stocks or for inland lakes in Ontario. Keleher (1952b) presented growth data for Lake Winnipeg blackfin ciscoes but experienced considerable difficulty distinguishing the various species of ciscoes in the lake; hence, some mixing of data is possible. His data is presented below:

Age (*years*)	SL (*inches*)	SL (*mm*)
2+	5.5	140
3+	5.4	138
4+	7.2	183
5+	8.9	225
6+	10.1	256
7+	11.3	287
8+	12.3	313
9+	12.3	313
10+	13.0	330
11+	13.0	330

In Lake Winnipeg, this species appeared to have a relatively rapid rate-of-growth, grew larger than any other cisco (attaining a maximum age of 11 years) and the available data there suggest that males matured at age 4 or 5, females at age 4. Maximum sizes are not known but Dymond (1926) gave a length of 15.3 inches (388 mm) for Lake Nipigon specimens. In the Great Lakes it was regarded as the largest of the deepwater ciscoes or chubs.

The blackfin was found mainly in the deep waters of large lakes, and in the Great Lakes was considered to inhabit deeper waters than most other species. In smaller inland lakes it lived in shallower water. It has been captured at depths of 600 feet (183 m) in lakes Huron and Superior and may have occurred at even greater depths. In Lake Nipigon, Dymond reported that it was taken at greater depths than any other species, to 340 feet (104 m), but in summer it occurred in numbers at depths of 120 feet (37 m).

The food in the stomachs of 56 individuals caught in Michigan waters of Lake Huron in September and October, 1917, and of 2 caught off Lion's Head, Georgian Bay, in October, 1919, was reported by Koelz (1929). *Mysis relicta* was almost the sole food, but one or two stomachs contained traces of plant fragments, insect remains, and a fish scale. All fish were caught at depths of more than 360 feet (110 m).

The blackfin cisco, along with the other deepwater ciscoes, formed the basic food of lake trout in the deep waters of Lake Superior and possibly also in Lake Huron and Lake Nipigon until the 1950's. Because of its relatively large size, for a cisco, it was also preyed upon by the sea lamprey (Moffett 1957). In inland lakes it is probably an important prey of larger predaceous fishes.

The cestode *Triaenophorus crassus* was present in the flesh of about 60% of the blackfin ciscoes from Lake Winnipeg examined by Keleher (1952b).

Relation to man The blackfin was a highly prized commercial species in the Great Lakes, especially in the smoked fish trade, but is no longer of commercial importance (*see* p. 230–231). It was usually caught in gillnets. It is still caught in inland lakes in Ontario and in Lake Winnipeg and elsewhere in Manitoba but is usually marketed under the general name tullibee.

Nomenclature

Argyrosomus nigripinnis — Gill (*in* Hoy 1872: 99) (type locality Lake Michigan off Racine)
Coregonus prognathus — Smith 1895: 4
Argyrosomus prognathus (H. M. Smith) — Evermann and Smith 1896: 314
Leucichthys prognathus (H. M. Smith) — Jordan and Evermann 1911: 23
Leucichthys nigripinnis (Gill) — Jordan and Evermann 1911: 26
— Dymond 1926: 62
— Dymond 1943: 218
Leucichthys cyanopterus Jordan and Evermann — Jordan and Evermann 1911: 27
Coregonus nigripinnis (Gill) — Hubbs and Lagler 1958: 55

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *nigripinnis* — *niger* — black, *pinna* — fin.

Common names Blackfin cisco, blackfin, black-fin tullibee, black-back tullibee, blackfin, mooneye cisco, bluefin. French common name: *cisco à nageoires noires*.

SHORTNOSE CISCO

Coregonus reighardi (Koelz)

Description Body elongate, average length to about 10 inches (254 mm), slightly compressed laterally but less so than other ciscoes; approaching the cylindrical form in cross section, greatest body depth in front of dorsal fin, 22–27% of total length. Head short, stout, 20–23% of total length; eye small, smaller than most species, 22.2–26.4% of head length; snout short, truncate in side view because of near vertical position of premaxillaries; mouth small, terminal, lower jaw included in upper jaw, not protruding beyond upper, maxillary extending posteriorly to below anterior half of eye. Gill rakers full range, total count 32–42, but 32–38 (Lake Ontario), 34–38 (Lake Nipigon), 32–42 (Lake Superior). Branchiostegal rays 8–10 (Lake Superior). Fins: all fins rather short; small dorsal adipose present, dorsal 1, rays 8–11, usually 9–11; caudal distinctly forked; anal rays 9–13, usually 10 or 11; pelvic rays 10–12; pectoral rays 15–17. Scales cycloid, large, 68–78 (Lake Ontario), 65–83 (Lake Superior), 64–77 (Lake Nipigon), in lateral line. Vertebrae 55–58.

Nuptial tubercles are developed on males and on at least some females.

(*See also* Koelz 1924, 1929; Dymond 1926; Pritchard 1931.)

Colour Overall colouration silvery; silvery iridescence on sides, white below. The back of Lake Ontario specimens was described by Pritchard (1931) as light greenish straw-coloured; he also remarked that none of the other species of cisco showed the typical yellow-green straw colour of *reighardi*. Premaxillaries heavily pigmented, maxillaries pigmented on cutting edge and lower jaw pigmented. Dorsal and caudal fins pigmented, but others usually immaculate.

Systematic notes This species was described by Koelz (1924). The holotype is a female with large eggs in the body cavity, 8.3 inches (210 mm) in standard length, caught in Lake Michigan April 1, 1921, at a depth of 180–210 feet (54.9–64.0 m). It is stored in the United States National Museum, cat. no. 87351, and was in excellent condition when examined in 1959. Koelz (1929) considered the populations in lakes Superior and Nipigon to differ significantly from those in lakes Ontario and Michigan. The typical subspecies *C. reighardi reighardi* was said to inhabit lakes Ontario and Michigan, while *C. reighardi dymondi* lakes Nipigon and Superior. The Nipigon form was considered to have fewer scales, more dorsal and anal rays, and a relatively longer head, maxillary, and pectoral fins.

Distribution The shortnose cisco was indigenous to the Great Lakes basin and was limited in distribution to lakes Ontario, Huron, Michigan, Superior, and Nipigon. Lake Huron specimens were unknown until 1956 (Scott and Smith 1962).

Biology Spawning occurred in western lake Ontario, mainly during April and the first two weeks of May, in about 250 feet (75 m) of water, according to Pritchard (1931). He noted he had been unable to determine when spawning ended, but a few ripe fish were found as late as the first week of June. A spent female was caught as early as January 26, but premature ripening of occasional individuals was not uncommon among the deepwater ciscoes. Captures by commercial fishermen suggested that spawning may have taken place somewhat later in eastern Lake Ontario.

In Lake Michigan spawning occurred chiefly in May and June at depths of 120–470 feet (36.6–144.5 m) at temperatures of 38.8°–40.5° F (3.8°–4.7° C), over sand, silt, silt and clay, or clay bottoms, according to Jobes (1943).

In the remaining Great Lakes (Michigan, Superior, and Nipigon) the shortnose cisco also spawned in spring, although the evidence available to Koelz (1929) led him to believe that spawning occurred in November.

In recent years changes in spawning behaviour have been noted. Smith (1964a) remarked upon the presence of large numbers of *C. reighardi* in spawning condition, in the fall, in an area in Lake Michigan where they spawned the previous spring. It was suggested that such a change might well increase the probability of hybridization with a fall-spawning species.

Information on fecundity, embryological development and early life history was apparently never published.

Ages can be determined from the scales and age analyses indicated that growth was relatively slow. Lengths and weights at ages 1–8, for lakes Ontario (Pritchard 1931) and Michigan (Jobes 1943) are given in the table below.

Females outlived males by about 2 years in Lake Michigan, where they attained age 8+ according to Jobes (1943). The oldest shortnose cisco reported by Pritchard (1931) for Lake Ontario was also 8+, and was probably a female. In Lake Ontario they grew at least to 14 inches (356 mm) long and 19 ounces (539 g) in weight.

In the Canadian waters of Lake Ontario, the shortnose cisco occurred at depths of 75–300 feet (22.9–91.4 m). Few were taken at depths of less than 75 feet and maximum numbers occurred at 250 feet (76.8 m). In Lake Nipigon, maximum numbers occurred at 90–100 feet (27.4–30.5 m).

The stomach contents of 27 specimens from Lake Ontario were examined by Pritchard. *Mysis relicta* and *Pontoporeia hoyi* were the major food items but small numbers of copepods, aquatic insect larvae, and fingernail clams were also eaten.

The following information on parasites applies to the former Lake Ontario population (Pritchard 1931). The copepod, *Salmincola inermis* occurred in 5% of specimens examined, the nematode *Cystidicola* in 45%, and an acanthocephalan, *Echinorhynchus* sp., in 45%. The latter parasite was not observed in any other cisco in Lake Ontario.

Relation to man This was once a valuable commercial species in Lake Ontario until at least the 1940's. Pritchard considered it one of the most important and valuable ciscoes taken in Canadian waters and Stone (1947) remarked that small catches were made in New York waters in the spring. Although *reighardi* was a rather small fish, averaging about one pound or less, it was very fat and considered excellent for smoking. It has become exceedingly rare in recent years in Canadian and United States waters of Lake Ontario. Wells (1969) reported two specimens caught in experimental fishing in United States waters during 1964–1966, and Christie (personal communication 1970) stated that only a few specimens had been seen in recent years.

It was also one of the important deepwater ciscoes in the "chub" fishery of lakes Michigan and Superior but it has largely disappeared from Lake Michigan and has been greatly reduced in numbers in Lake Superior. Its status in Lake Nipigon is unknown. For further information on this species in relation to the chub fishery, *see* p. 230–232.

		Age (*years*)							
		1+	2+	3+	4+	5+	6+	7+	8+
	FL								
L. Ontario	*inches*	7.3	–	9.7	9.9	10.6	10.0	11.4	11.1
	mm	185	–	246	251	269	254	290	282
	Wt (*oz*)	1.8	–	6.8	7.8	9.1	7.1	12.6	14.8
	TL								
L. Michigan	*inches*	–	10.4	10.7	10.9	11.2	11.4	–	–
	mm	–	264	272	277	284	290	–	–
	Wt (*oz*)	–	5.7	6.1	6.1	6.6	7.1	–	–

Nomenclature

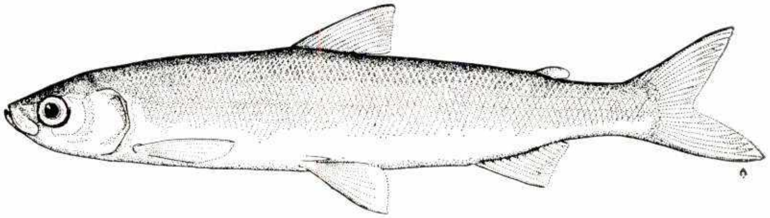
Leucichthys reighardi	— Koelz 1924: 5 (type locality Lake Michigan, 18 miles NxW off Michigan City, Ind.)
Coregonus reighardi (Koelz)	— Hubbs and Lagler 1958: 54

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye) and angle; *reighardi* — in honour of Jacob Reighard, a well-known and respected ichthyologist, Department of Zoology, University of Michigan.

Common names Shortnose cisco, Reighard's chub, Reighard cisco, shortnose chub, greaser. French common name: *cisco à museau court*. The term "greaser" is from Stone (1947: 234) in reference to specimens from Lake Ontario, N.Y.

LEAST CISCO

Coregonus sardinella Valenciennes

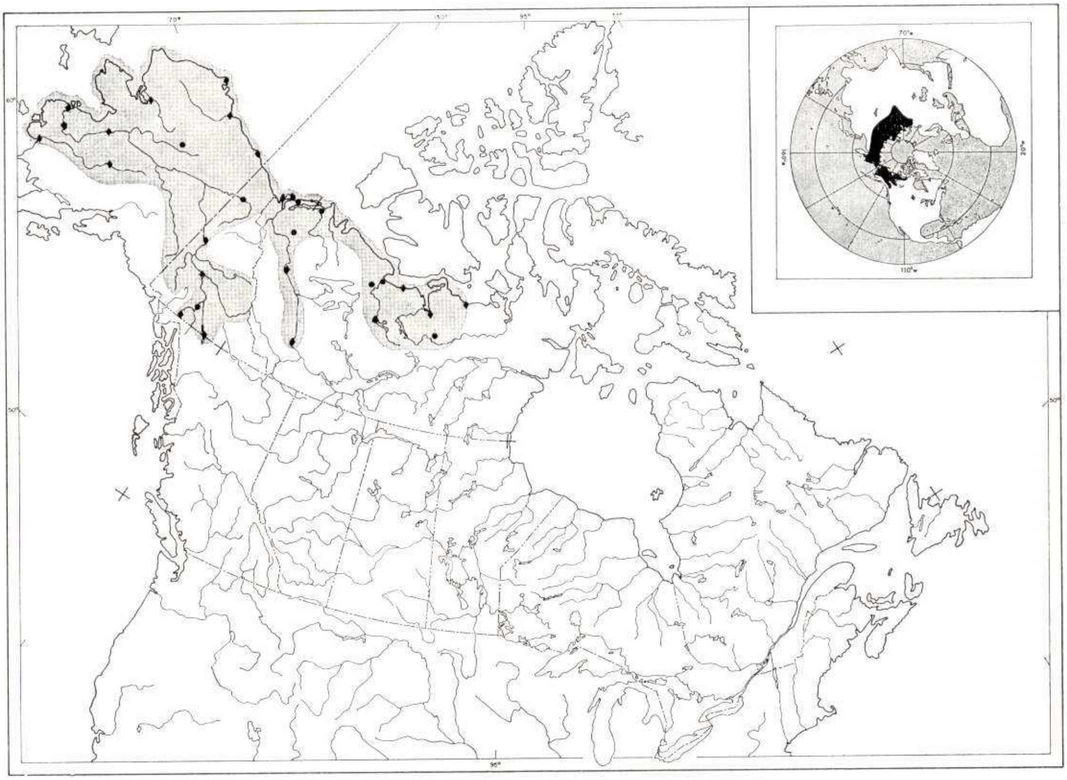


Description Body elongate, length to about 8–10 inches (203–254 mm), somewhat compressed laterally, greatest body depth at front of dorsal fin 19–24% of total length. Head about 19–24% of total length; eye large, its diameter 26–32%; snout length usually less than eye diameter; mouth moderate, terminal, lower jaw always protruding, maxillary at a distinct angle, extending posteriorly to below anterior half of eye; a small cluster of teeth on tongue. Gill rakers, total count 42–53. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, high, falcate, rays 12–14; caudal distinctly forked; anal rays 11–13; pelvic rays 8–12, a distinct pelvic axillary process present; pectorals narrow, pointed, rays 14–17. Scales cycloid, large, 78–98 in lateral line. Pyloric caeca 74–111. Vertebrae 58–64.

Nuptial tubercles presumably developed on scales on flanks of males.

This species occurs in both fresh water (nonmigratory) and marine (migratory) forms. The latter is often larger and heavier than the former, and there are other differences such as colour. *See also* McPhail and Lindsey (1970).

Colour Overall colouration silvery; usually brown to dark green on the back, becoming silvery on sides and below. The small non-anadromous form that remains in fresh water is without spotting on back and only the pelvic fins have black pigment on tips,



the remaining fins are unpigmented. The larger, anadromous form has dark spots on head, back, dorsal, and adipose fins and, sometimes, on pectoral fins; all fins usually have dark pigment on tips.

Systematic notes This species was described by Valenciennes (1848) based on specimens from the Irtysh and Kolyma rivers, Siberia. For many years northern North American populations were referred to *Coregonus pusillus* Bean, but Dymond (1943) noted the similarity of *pusillus* to *sardinella* and recommended that *pusillus* be regarded as a synonym. At present, North American populations are not distinguished taxonomically from those in Siberia, but in a recent treatment, McPhail and Lindsey reviewed the North American systematic history of the species, drawing particular attention to the existence of two forms or types: one that lives out its entire life in fresh water (nonmigratory) and another form that ascends rivers in summer from arctic seas and descends again in late autumn (migratory). The differences in size, colour, and morphometry emphasize the existence of two well-marked forms. The migratory form has a gill raker range of 48–53, mean about 50, while the freshwater form has a range of 41–47 with a mean near 45; some exceptional Alaskan populations were noted. These authors have called the least cisco populations *"Coregonus sardinella"* complex. Their account should be consulted for additional details.

Distribution The least cisco occurs in coastal waters and in certain inland lakes and rivers in northern Europe, Asia, and North America, from the White Sea region west to Alaska and the Northwest Territories.

In North America it occurs in many inland waters and most of coastal Alaska north of Bristol Bay, including the Arctic Ocean drainage. In Canada it occurs in many inland waters (Atlin, Teslin, and Swan lakes in extreme northern British Columbia and Yukon Territory, the Mackenzie, Peel and lower reaches of many arctic rivers) and in arctic coastal waters east at least to Bathurst Inlet; north to Victoria and Banks islands.

Biology The biology of the least cisco has been little studied in Canada and, hence, little direct information is available; but many studies have been made on Siberian populations and some work has been done in Alaska. Much of this information has been summarized by Nikol'skii (1954) and by McPhail and Lindsey (1970).

The biology of the least cisco is somewhat complicated by the existence of migratory and nonmigratory populations. Spawning occurs in autumn, usually in September or October in Siberia. The eggs are deposited over sand or gravel in shallows of rivers or along lake shores, and abandoned by the spawners, as is usual among whitefishes. In the Yenisei River, Siberia, females carry from 2500–23,600 eggs. The eggs remain over winter on the bottom, and hatch the following spring. In the USSR the larvae of the migratory forms, upon hatching, move downstream toward the sea.

Growth rates of migratory forms are usually greater than those of nonmigratory or freshwater forms, and migratory forms usually reach a greater maximum age. The oldest fish at Teslin Lake, B.C., and Yukon Territory (a freshwater population) was 8 years old, weighed 4 ounces (113 g), and was 9.8 inches (249 mm) long; the largest was 6 years old, weighed 11 ounces (312 g), and was 10.9 inches (276 mm) long. Studies by Cohen (1954) in Alaska indicated that migratory forms reached 11 years of age, freshwater populations only 9. In Siberia the maximum age attained was also 11 years (Nikol'skii). Some Canadian populations may attain much greater ages, for specimens from Victoria Island, N.W.T., attained ages approaching 26 years (J. G. Hunter, personal communication). Migratory forms may reach a length of 16.5 inches (419 mm), freshwater forms 9 inches (229 mm).

Throughout its coastal range the migratory form of the least cisco exhibits an upriver migration in spring and summer; following spawning in the autumn the populations again move downstream.

In Siberian waters, planktonic crustaceans are the main foods but river populations apparently feed also on aquatic and terrestrial insects.

It is said to be eaten by lake trout, inconnu, northern pike, and burbot in Atlin and Teslin lakes in northern British Columbia (Carl et al. 1967).

Studies of the mortality rates of this species in Ikroavik Lake, Alaska, indicated that only 5% of all sizes were noticeably parasitized but the parasites involved were not identified (Wohlschlag 1954a, b). Parasites of this species in waters of the USSR, as compiled by Bykovskaya-Pavlovskaya et al. were listed by Lawler (1970).

Relation to man The least cisco is not considered to be of much commercial importance in North America because of its small size and slow growth rate (Dymond 1943; Cohen 1954), but it constitutes one of the most important commercial fishes in the lower reaches of Siberian rivers. It is caught incidentally in the Mackenzie River (and possibly others) in gillnets set for other whitefishes. Wynne-Edwards (1952) noted that it was caught with a hook by children at Carcross, southern Yukon Territory, where it occurred in large numbers in summer. Although it is of small size, the flesh is said to have an excellent flavour.

Nomenclature

Coregonus sardinella	— Valenciennes 1848 (*in* Cuvier and Valenciennes 1828–49) (type locality Irtysh and Kolyma rivers, Siberia)
Coregonus pusillus	— Bean 1889: 526
Argyrosomus pusillus (Bean)	— Jordan and Evermann 1896–1900: 470
Leucichthys pusillus	— Dymond 1943: 204
Leucichthys sardinella (Valenciennes)	— Carl and Clemens 1948: 38

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *sardinella* — small sardine.

Common names Least cisco, lake herring, cisco, big-eye Mackenzie herring. French common name: *cisco sardinelle*.

SHORTJAW CISCO

Coregonus zenithicus (Jordan and Evermann)

Description Body elongate, average length to about 11 inches (279 mm), more compressed laterally than most other deep-water ciscoes; greatest body depth in front of dorsal fin, 19–27% of total length. Head elongate but not deep, its length 22.8–27.0% of total length; eye moderate, its diameter 19.7–25.6% of head length; snout usually longer than eye diameter, its length 25.0–32.2% of head length; mouth moderate, terminal, lower jaw included in upper jaw or lower jaw protruding (latter more usual in inland populations), maxillary long, (hence the oft-used commercial name, "longjaw"), extending to middle of eye or slightly beyond. Gill rakers, full range total count 32–46, but 34–44 in Lake Huron, 32–46 in Lake Superior, 33–42 in Lake Nipigon, 34–40 in lakes Winnipeg and Athabasca. Branchiostegal rays 8–10. Fins: small adipose dorsal present; dorsal 1, rays 9–11, usually 10 or 11; caudal distinctly forked; anal rays 10–13, usually 11 or 12; pelvic rays 11 or 12, a distinct pelvic axillary process present; pectoral rays 15–18, usually 16 or 17. Scales cycloid, large, lateral line with 70–88 in Lake Huron, 69–90 in Lake Superior, 66–83 in Lake Nipigon, 58–69 in lakes Winnipeg and Athabasca. Vertebrae 54–58 (Lake Nipigon).

Nuptial tubercles developed on males.

(*See also* Dymond 1926; Koelz 1929; Dymond and Pritchard 1930.)

Colour Overall colouration silvery; usually greenish on back, becoming silvery on sides, with purplish iridescence, and white below. Pelvic and anal fins usually immaculate or only lightly pigmented, pectorals lightly pigmented, but dorsal and caudal fins sometimes darkly pigmented.

Systematic notes This species was described by Jordan and Evermann (1909). The holotype is a male, 278 mm standard length, 12.0 inches (305 mm) fork length, caught by John Coventry in Lake Superior in September 1908, off Isle Royale. It is stored in the United States National Museum, cat. no. 62517 and was in excellent condition when examined in 1959.

This is one of the problem ciscoes, taxonomically speaking, for, although it was rather readily recognizable in the Great Lakes, reports of its occurrence elsewhere in Canada have often been viewed with lingering doubts. Dymond and Pritchard (1930) reported *zenithicus* from Lake Winnipeg, Man., and from Lake Athabasca, Alta., Dymond (1943) included Reindeer Lake, Sask., in the range, and also the Northwest

Territories, the latter based on descriptions of new species by Harper and Nichols (1919) (*Leucichthys athabascae*, *L. entomophagus* and *L. macrognathus*) which he (Dymond) considered to be synonyms of *zenithicus*.

In a discussion of *"Coregonus artedii"* complex in northwestern Canada, McPhail and Lindsey (1970) questioned Dymond's decision concerning *athabascae*, *entomophagus*, and *macrognathus*, indicating that, upon a restudy of the holotypes, that were stored in the National Museum of Canada, ". . . Dymond's (gill raker) counts are consistently low" and that the revised gill raker counts were, *athabascae* 40+ (damaged), *entomophagus* 37, and *macrognathus* 42, instead of 35, 35, and 37, respectively, as reported by Dymond. Therefore, only *entomophagus* could be considered a synonym since gill rakers of the other two fell within the range of *artedii*. In all fairness, however, it should be pointed out that Dymond (1943, p. 216) explained in a footnote that the count of 35 for *athabascae* was taken from Harper and Nichol's own account, and was not a count that he made personally. McPhail and Lindsey's discussion of *zenithicus*, however, implied a dependency on gill raker counts alone as a means of identifying the species, and, in our experience, *zenithicus* may have gill raker counts up to 46. For example, in Lake Superior, the type locality, *C. zenithicus* has a gill raker range of 32–46.

White Partridge Lake, in the vicinity of Algonquin Park, Ont., and a few other glacial lakes in the area, have populations of ciscoes that mature at lengths under 4 inches (100 mm), have gill raker counts of 38–42, and head and body measurements that are typical of *zenithicus*. It is expected that many more populations of such small ciscoes will be found in other parts of the country. We have also examined specimens from Alberta (Paterson 1969) which conformed to the classical description of *zenithicus*, but which were of large size.

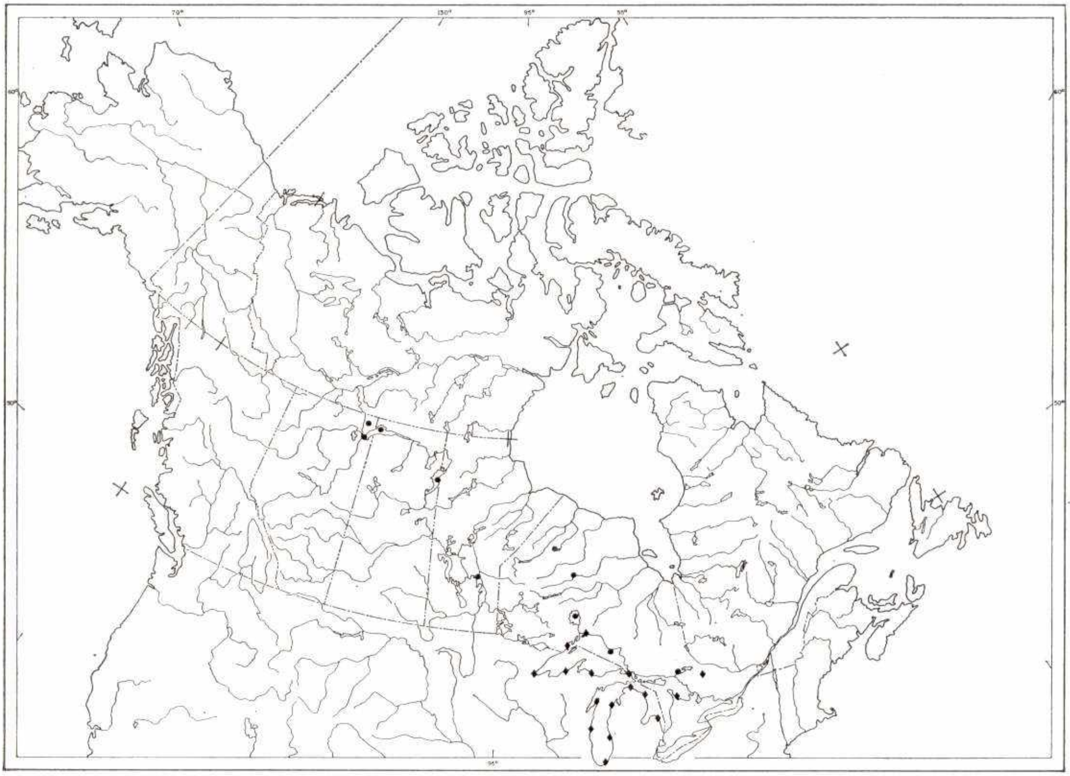
The species identified as *zenithicus* in Lake Winnipeg (re-examined by Keleher (1952b)) was recognized primarily by means of gill raker counts but was not readily distinguishable by other features (although Keleher's differential correlations of *Triaenophorus* parasitism with different species of ciscoes are of considerable interest). These and other observations clearly indicate that the verification of the presence of *Coregonus zenithicus* in waters other than the Great Lakes must await considerably more investigation of the subgenus *Leucichthys* in Canadian lakes than has been attempted heretofore.

Distribution The complete range of the shortjaw cisco is not fully known. In the Great Lakes basin, it was formerly caught in lakes Huron, Michigan (probably extirpated), Superior, and Nipigon. North and west, fish described as this species have been reported from Lake Winnipeg, Man., Reindeer Lake, Lake Athabasca, Sask., Barrow Lake, Alta., by Paterson (1969), and Great Slave Lake, N.W.T. Dwarf specimens have also been reported from inland lakes in and around Algonquin Park, Ont. There are indications that small or dwarf *zenithicus*, which mature at lengths of less than 5 inches (127 mm), may be more widely distributed in inland lakes than was previously thought.

Biology Spawning takes place in the fall but the time apparently varies from lake to lake. In Lake Huron observations by Koelz (1929) suggested that spawning occurred between September 28 and October 14, 1917, while in Lake Nipigon spawning was thought to occur about the first part of November. In Lake Superior, studies by Koelz (1929) and Van Oosten (1937a) indicated that spawning occurred in late November or early December, probably at a depth of 120–240 feet (37–73 m), over a clay bottom.

Information on fecundity, embryological development, and early life history have not, apparently, been published.

Age can be determined by scale analysis. A study of *zenithicus* from Lake Superior by Van Oosten (1937a) from specimens collected in 1922, suggested that growth was rapid in the first year, and slower in subsequent years. Gain in weight was slow during the first four years but during the fifth and sixth years a rapid increase in weight



occurred (53% in males and 66% in females). It was suggested that the species be protected until at least its sixth year, when it reached a total length of about 10.3 inches (262 mm). Males and females grew at about the same rate but females tended to be heavier than males at corresponding lengths and ages, and females also lived longer and, hence, reached a larger size than males. The largest male reported by Van Oosten from Lake Superior was 13.8 inches (351 mm) long and weighed 9.7 ounces (276 g), the largest female, 14.5 inches (368 mm) long, weighed 10.3 ounces (292 g). Lengths and weights of *zenithicus* from Lake Winnipeg and Lake Superior are given in the table below.

This is a deepwater species that ranges in depth from about 60–600 feet (18–183 m) in the Great Lakes. In Lake Superior, Dryer (1966) observed seasonal depth distribution of 360–414 feet (110–144 m) in spring, 180–234 feet (55–71 m) in summer, and 240–294 feet (73–90 m) in winter. Throughout the seasons it was most common at 180–414 feet (55–144 m). In inland waters in

		Age (*years*)								
		2+	3+	4+	5+	6+	7+	8+	9+	10+
	TL									
L. Superior	*inches*	–	–	9.2	10.9	11.7	12.3	12.8	13.8	13.6
(Van Oosten	*mm*	–	–	234	277	297	312	325	351	345
1937a)	Wt (*oz*)	–	–	2.7	4.4	5.3	6.0	7.0	8.8	8.8
	SL									
L. Winnipeg	*inches*	5.4	5.3	7.2	8.7	9.4	9.8	10.1	10.9	–
(Keleher 1950)	*mm*	138	135	182	221	240	250	258	277	–

Ontario it has been captured in glacial lakes of 100–150 feet (30.5–45.7 m) in depth in which *Mysis relicta* and *Percopsis omiscomaycus* were also found (Martin and Chapman 1965).

In the Great Lakes the primary food items appear to have been *Pontoporeia hoyi* and *Mysis relicta* but planktonic Crustacea and aquatic insect larvae were also found in stomachs. Bajkov (1930) reported similar food eaten by Lake Winnipeg specimens.

The shortjaw cisco formed a part of the natural diet of the lake trout and burbot in the Great Lakes, and, following the arrival of the sea lamprey, the shortjaw was probably preyed upon directly by it as well. Small, dwarfed ciscoes, presumed to be this species, are commonly observed in stomachs of lake trout caught in glacial lakes in the vicinity of Algonquin Park, Ont.

Keleher (1952b) reported a fairly high degree of infection of Lake Winnipeg *zenithicus* by *Triaenophorus crassus*, but could find no correlation between degree of infection and age.

Dead *zenithicus* found on shores of White Partridge Lake, Algonquin Park, Ont., had large numbers of a species of *Diphyllobothrium* blocking heart vessels; the parasites were considered numerous enough to have caused death (R. S. Freeman, personal communication).

Hoffman (1967) listed the cestodes *Cyathocephalus truncatus* and *Proteocephalus laruei*, parasites of this species in North American fresh waters.

Relation to man This species was once considered of importance in the Great Lakes "chub" fishery (*see* p. 231) of lakes Michigan and Huron. It no longer exists in Lake Michigan and its status in Lake Huron is unknown. It is probably one of the more common ciscoes in Lake Superior but its importance there and in Lake Nipigon is not known. In 1937, Van Oosten wrote that it was the only large chub that was common enough to be taken in commercial quantities.

In Manitoba, *zenithicus* was formerly an important part of the "tullibee" fishery and was mainly exported to the United States for the smoked fish market.

Nomenclature

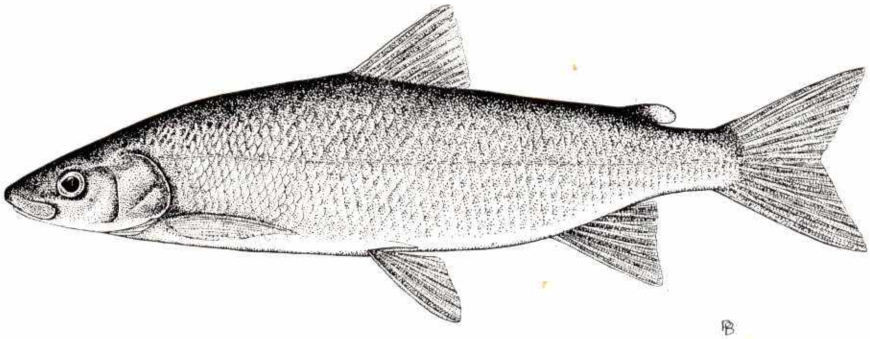
Argyrosomus zenithicus	— Jordan and Evermann 1909: 169 (type locality deep water off Isle Royale, L. Superior — between Duluth and Isle Royale)
Leucichthys entomophagus	— Harper and Nichols 1919: 267
Leucichthys athabascae (?)	— Harper and Nichols 1919: 269
Leucichthys macrognathus (?)	— Harper and Nichols 1919: 269
Leucichthys zenithicus (Jordan and Evermann)	— Dymond 1926: 65
	— Dymond 1943: 215
Coregonus zenithicus (Jordan and Evermann)	— Hubbs and Lagler 1958: 54

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *zenithicus* — named after Duluth, "the Zenith City," where "Hundreds of specimens of this species were seen in the cold-storage plant of Booth and Company."

Common names Shortjaw cisco, shortjaw chub, longjaw, light-back tullibee, pale-back tullibee, short-jaw chub, Lake Superior longjaw. French common name: *cisco à mâchoires égales.*

LAKE WHITEFISH

Coregonus clupeaformis (Mitchill)



Description Body elongate, average length to about 15 inches (381 mm), small fish usually slender but large fish may be somewhat ovate in lateral view, compressed laterally, greatest body depth at front of dorsal fin but depth variable, greater in mature females than males and increasing with increase in weight, but usually 23–33% of total length. Head short, 20–23% of total length, large, old fish may develop a hump behind head, (nuchal hump) also common on fish from northwestern Canada; eye small, its diameter 19.5–25.0% of head length; snout projecting beyond mouth, its length 27–35% of head length; mouth inferior, distinctly overhung by snout, maxillary extending posteriorly to about the anterior edge of the pupil, maxillary length 22–28% of head length; 6–8 small, weak teeth present on premaxilla to 30–40 mm stage, and an occasional tooth at lengths to 84 mm, teeth also on dentary at lengths to 80 mm but absent on adults, weak teeth also on lingual plate. Gill rakers, extreme range 19–33, seldom fewer than 22 in eastern Canada; length of longest gill raker 22–44% of interorbital width. Branchiostegal rays 8–10. Fins: dorsal adipose present; dorsal 1, rays 11–13; caudal distinctly forked; anal rays 10–14; pelvic rays usually 11, sometimes 12, pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large, extreme range 70–97 in lateral line, a heavy overlay of mucus or slime overlays the scales and causes whitefish to feel more slimy than ciscoes. Pyloric caeca 140–222. Vertebrae 55–64 (range in Lake Opeongo, Algonquin Park, Ont., 55–63).

Nuptial tubercles or pearl organs developed on scales on flanks of breeding males, smaller and fewer on females; on males they are well developed on at least 3 rows of scales above the lateral line and on 6 rows below.

(*See also* Koelz 1929, 1931; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; back pale greenish brown (Great Lakes) or light brown and sometimes dark brown to almost black (inland lakes), becoming silvery on the sides and silvery white below. In northwestern Canada, lake whitefish exhibit darkened scale margins, lending a darker colour than that of eastern fish on which the scale pattern is lacking or only weakly developed. The fins are usually clear or only lightly pigmented in the Great Lakes but farther north the fins are often darker and are usually black tipped.

Systematic notes The lake whitefish was described by Mitchill in 1818, as *Salmo clupeaformis* from St. Mary's River below the falls, at the northern extremity of Lake Huron. The holotype does not exist and as Koelz (1929) indicated, Mitchill's description was inadequate.

Coregonus clupeaformis has presented a confused taxonomic picture, particularly in northwestern North America where, in addition to the existence of Eurasian forms such as *C. nasus* and possibly also *C. pidschian*, inadequate and poorly preserved specimens were available for study. As an example of this confusion, *C. clupeaformis* was equated or synonymized with three different Eurasian species by three different authors (Walters 1955; Svärdson 1957; and Gasowska 1960). Considerable clarification was achieved when the distinctness of *clupeaformis* from *nasus* was ably demonstrated by Lindsey (1962) but many problems remain. In various parts of North America there exist sympatric pairs of whitefish species that differ significantly in growth rate, size at maturity, and other features, but usually are not distinguishable by the usual morphometric and meristic characters, such as gill rakers. Such populations are usually referred to as "dwarf" and "normal" whitefish and have been shown to occur in Algonquin Park, Ont., (Kennedy 1943), Maine (Fenderson 1964) and possibly Lake Superior (Edsall 1960). Other similar sympatric populations are known to exist. Such a case was noted for Lake Simcoe by MacCrimmon and Skobe (1970), and McPhail and Lindsey (1970) mentioned others. Even so, eastern North American populations seem less complex than those in the northwest. McPhail and Lindsey found it expedient to refer to the North American lake whitefishes as "*Coregonus clupeaformis*" complex, in recognition of the systematic problems existing in the northwest. *Coregonus nelsoni* Bean was included in the complex, but *see* Lindsey (1962, 1963). They provided an excellent review which should be consulted.

The investigation of protein characters, using electrophoretic techniques, offers attractive alternatives to traditional systematic methods. Some of these methods have been applied to *C. clupeaformis* by Lindsey et al. (1970). Cytogenetic parameters have also been applied by Booke (1968), who provided karotypes of this and other coregonine species.

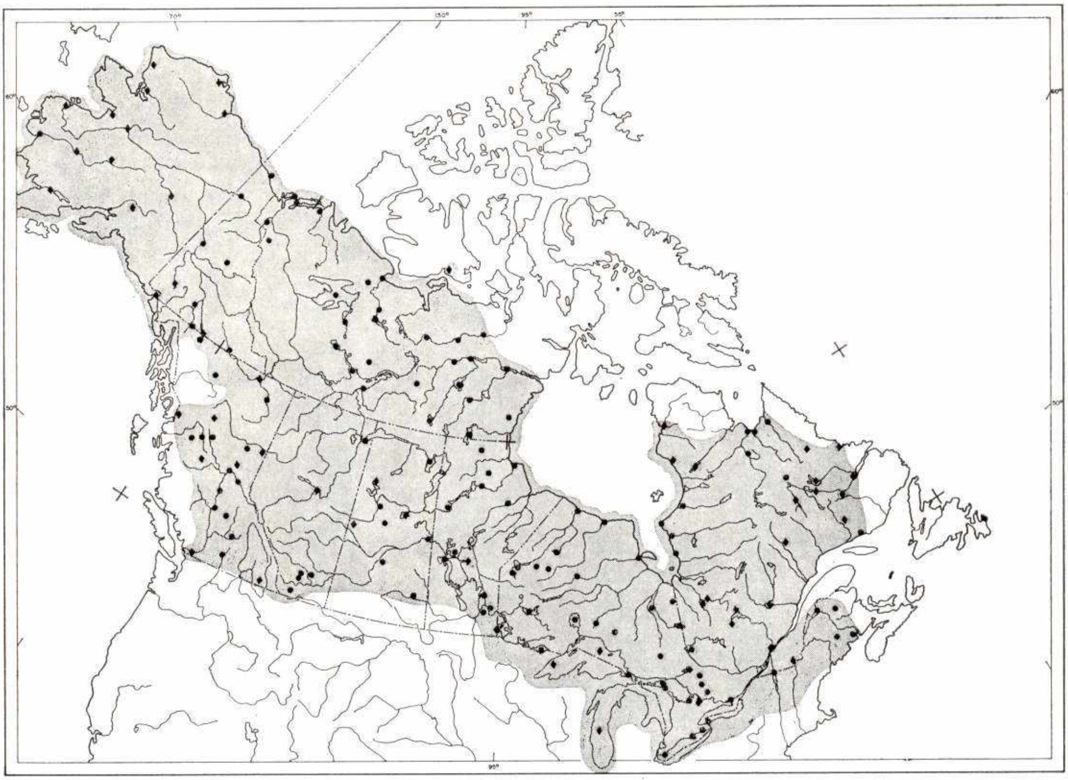
In the Great Lakes, particularly in Lake Erie, hybrids between *C. clupeaformis* and *C. artedii* were well known as "mules" or "mule whitefish." They were remarkably bright green in colour but the shape of the mouth and the gill raker counts were intermediate between those for the parental species. The hybrids also exhibited very accelerated growth rates and attained weights of 2.5–3.0 pounds (1134–1361 g) at 2 years of age and one weighed 6.7 pounds at age 5. A "mule" weighing nearly 12 pounds (5.4 kg) was noted by Koelz (1929) but no age was given.

Distribution The lake whitefish is widely distributed in North American fresh waters from the Atlantic coastal watersheds westward across Canada and the northern United States, to British Columbia, the Yukon Territory, and Alaska.

In Canada, it occurs from New Brunswick and Labrador west throughout Quebec, including Ungava, throughout Ontario including the Great Lakes, to coastal waters of Hudson Bay, throughout Manitoba and in suitable waters of Saskatchewan (especially in the north), Alberta, and British Columbia, and is generally distributed throughout the Territories, in most large lakes and larger rivers. In Ungava, the Hudson Bay region, and Arctic Ocean drainages in the Northwest Territories it enters brackish water. The northern limit of range in Canada is near Cambridge Bay, Victoria Island, N.W.T.

It has been introduced into many parts of Canada (British Columbia, insular Newfoundland, Alberta) as a forage fish or in hopes of establishing commercial fisheries. (*See* Dymond 1936; Cuerrier and Schultz 1957; Scott and Crossman 1964; Carl et al. 1967.)

Biology The biology of the lake whitefish has received considerable study, mainly because it has long been an important commercial species. Nevertheless, many aspects of its natural history have remained obscure, in particular, the movements and habits of young-of-the-year, which only recently have received much needed attention (Faber 1970; Reckahn 1970).



Spawning occurs in the fall, usually November and December in the Great Lakes region and generally earlier farther north but the exact date of spawning varies from year to year, even in the same lake. In Heming Lake, Man., spawning occurred mainly between October 19 and 25, 1953 (Lawler 1965a). In Great Slave Lake, spawning occurred from late September to October (Rawson 1947). In Lake Erie, Lawler (1965a) concluded that spawning was generally delayed until the temperature dropped to approximately 46° F (7.8° C) and that the spawning peak occurred at a lower temperature. In extreme northern waters, available evidence suggests that individuals may spawn only every second or third year.

Spawning usually occurs in shallow water at depths of less than 25 feet (7.6 m), but spawning in deeper water has been reported by Koelz (1929). It often takes place over a hard or stoney bottom but sometimes over sand. The number of eggs deposited by a female varies from population to population and tends to increase with size of female. The number of eggs per pound of fish has been calculated to be 16,100 for Lake Erie (Lawler 1961), (possibly high since counting was done in August on "green" eggs), 9900 for Lake Ontario (Christie 1963), and 8200 for Lake Huron (Cucin and Regier 1965). For a discussion of egg number and spawning potential *see* Christie (1963) and Cucin and Regier (1965). Female whitefish in Lake Erie have been calculated to lose approximately 11% of their weight at spawning (Van Oosten 1939). On extrusion, eggs measure about 2.3 mm in diameter but after 24 hours in water the size increases to 3.0–3.2 mm (Hart 1930).

The eggs are deposited more or less randomly over the spawning grounds by the parents. Observations of Lake Ontario stocks by Hart (1930) supported the view that spawning fish are active and may jump and thrash about, especially at night. Leaping completely out of the water by spawning whitefish was observed and reported to us by the late Dr A. E. Allin. The eggs remain on the spawning ground until they hatch in April or May.

The embryology and rate of development of whitefish eggs are well known because of fish hatchery work. The collection of whitefish eggs from spawning fish, their retention and incubation in hatcheries, and the subsequent release of eyed eggs and larvae in spring has been practiced since the last century (*see* section on *Relation to man*). For detailed information on egg and larval development, *see* Hart (1930) and Fish (1932); for information on the effects of temperature on egg development *see* Price (1940) and Lawler (1965a).

Under experimental conditions, normal development occurs over a temperature range of 33°–43° F (0.5°–6.1° C), with the optimum temperature close to 33° F (Price 1940). Mortalities and abnormalities increase with higher temperatures until eggs incubated at 50° F (10° C) suffer 99% mortality. The ecology of newly hatched whitefish, in nature, received little attention, except for the work by Hart (1930), until the recent work by Faber (1970) and Reckahn (1970). They noted that the larvae formed aggregations along steep shorelines and were associated at this time with larvae of burbot, cisco (*C. artedii*), the deepwater sculpin, and smelt. Young whitefish generally leave the shallow inshore waters by early summer and move into deeper water.

Like most coregonines, age can be determined by scale examination. An abundant literature on the subject exists, but *see* Hogman (1968) for a recent review.

The rate of growth of lake whitefish varies from lake to lake, but in general is relatively rapid. The generally accepted commercial size of 2 pounds (0.9 kg) is reached at different ages in different lakes but the age at which this size is reached ranges from an exceptional age 3 (Lake Erie) to age 4 in Lake Winnipeg, age 9 in Great Slave Lake, N.W.T., and age 10 at Lac la Ronge, Sask. In Lake Simcoe, the common lake whitefish attains weights of about 0.75–1.25 pounds (340–567 g) at ages of 6–9 years, but there are some faster-growing whitefish that attain a weight of 1 pound (454 g) at age 3 or 4 (MacCrimmon and Skobe 1970).

In all populations, males usually mature at a younger age than females and die earlier.

Growth rates for a number of Canadian populations are shown in the table, p. 273.

The existence of dwarf whitefish has been reported by Kennedy (1943), Fenderson (1964), and Edsall (1960). The table on p. 274 shows the growth rate (age–length relation) of dwarf whitefish, *Coregonus clupeaformis*, and of normal sympatric whitefish populations.

Lake whitefish attained sizes to 20 pounds or more in the Great Lakes 50 or more years ago. The maximum size is probably one reported by Van Oosten (1946) that weighed 42 pounds and was caught off Isle Royale, Lake Superior, about 1918. A whitefish weighing 24 pounds was reportedly caught in Lake Winnipeg in 1923–1924 (Keleher 1961). In Great Slave Lake, a lake whitefish, aged 28 years and weighing 12.75 pounds, (5.8 kg) was recorded by Kennedy (1953b) and seems to be about the oldest recorded. Almost as old were the fish reported by Hart (1931) from Shakespeare Island Lake that lived to age 27. The heaviest whitefish from Great Slave Lake was reported by Keleher (1961) to weigh 22 pounds (10 kg).

The lake whitefish is a cool water species, as indicated by temperatures required for successful incubation of its eggs. Over most of the southern part of its range it descends into the cooler waters of the hypolimnion during summer months. Such movement may be unnecessary in northern lakes lacking critical thermal stratification. Throughout most of the Great Lakes, these fish move from deep to shoal waters in early spring and back to deeper water as warming occurs. In the fall, of course, whitefish move into shallow water to spawn. In Lake Superior, Dryer (1966) reported no whitefish below 240 feet (73 m) and gave an all-season depth distribution of 60–174 feet (18–53 m), but Koelz (1929) noted that whitefish were caught during summer to depths of 420 feet (128 m).

		Age (*years*)																
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
Eastern L. Ontario	FL	–	–	15.7	16.7	16.9	17.0	17.5	18.2									
and Bay of Quinte	*inches*	–	–	399	424	429	432	445	462	18.5	20.0	–	–	–	–	–	–	–
(Christie 1963)	*mm*									470	508	–	–	–	–	–	–	–
L. Erie (Van Oosten	TL																	
and Hile 1949)	*inches*	12.0	14.5	17.5	18.7	20.0	21.0	22.0	23.3	23.3	23.5	23.8	24.7	25.0	25.2	–	26.6	–
	mm	305	368	445	475	508	533	559	592	592	597	605	627	635	640	–	676	–
	Wt (*lb*)	0.56	1.1	2.0	2.5	3.0	3.6	4.1	5.4	5.0	4.9	5.4	6.2	6.9	6.9	–	8.8	–
Southern Georgian Bay,	FL																	
L. Huron (Cucin	*inches*	–	–	17.0	18.1	19.2	20.2	21.2	21.8	23.0	–	–	–	–	–	–	–	–
and Regier 1965)	*mm*	–	–	432	460	488	513	538	554	584	–	–	–	–	–	–	–	–
L. Superior, U.S. shore	TL																	
(Dryer 1963)	*inches*	9.1	14.0	16.4	18.2	18.8	19.1	18.4	18.5	20.8	24.5	–	–	–	–	–	–	–
	mm	231	356	417	462	478	486	467	470	528	622	–	–	–	–	–	–	–
	Wt (*lb*)	0.2	0.9	1.5	2.1	2.4	2.5	2.2	2.2	3.2	5.6	–	–	–	–	–	–	–
L. Winnipeg, Man. (Kennedy 1954a)	Wt (*lb*)	–	–	1.7	2.1	2.4	2.6	2.8	3.0	3.4	3.6	4.0	4.3	6.1	6.3	8.0	–	8.3
Lac la Ronge, Sask.	FL																	
(Qadri 1968)	*inches*	–	7.0	8.5	9.6	11.0	12.1	13.3	14.3	15.4	16.5	17.3	18.2	19.0	20.0	20.8	22.6	–
	mm	–	178	216	244	279	307	338	363	391	419	439	462	483	508	528	574	–
	Wt (*lb*)	–	.15	.24	.41	.6	.76	1.1	1.4	1.7	2.0	2.2	2.7	3.0	3.6	4.5	5.4	–
Great Slave L., N.W.T. (Kennedy 1953b)	Wt (*lb*)	–	–	–	–	–	–	–	1.5	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.5	3.7
Nueltin L., N.W.T. (Kennedy 1963)	Wt (*lb*)	–	–	–	–	–	–	–	1.7	3.1	3.7	3.9	4.2	4.4	5.2	4.6	5.3	–

Tagging studies in Lake Huron and Georgian Bay, (Budd 1957b) indicated a general tendency for the fish to move in definite directions although no well-defined routes were observed. Fish tagged in South Bay in the spring tended to return the following spring. One whitefish was recaptured in southern Lake Huron, 150 miles from where it was tagged.

Whitefish are usually regarded as schooling fishes, although Faber (1970) did not consider the aggregations of larvae to fall within accepted definitions of schooling (Keenleyside 1955).

Adult lake whitefish are bottom feeders over most of the range, consuming a wide variety of bottom-living invertebrates and small fishes. In some regions, however, planktonic creatures form a large part of the diet, and even terrestrial insects may be taken at the surface (Clemens et al. 1923). Relationship between the number and length of gill rakers, and the types of food consumed has been noted by McPhail and Lindsey and was investigated by Kliewer (1970), who found gill raker length correlated with food type to such a degree that fish with short rakers and high gill raker counts ate a higher proportion of benthic food.

In a recent study of young whitefish in Lake Huron, Reckahn (1970) noted that copepods, especially *Diaptomus*, were important initially, cladocerans became significant later in spring and by early July bottom organisms began to enter the diet, although cladocerans, especially *Bosmina*, remained dominant. As the young moved into deeper water, the diet began to resemble that of the adults and more aquatic insect larvae, especially chironomids, gastropods, fingernail clams (*Pisidium* spp.), amphipods (*Pontoporeia*), isopods, and ostracods were eaten; but planktonic crustaceans continued as dietary items.

The food of adult whitefish has received considerable attention, but few quantitative, in-depth studies have been made. Food varies from region to region but aquatic insect larvae, molluscs, and amphipods are primary foods. The diet of Great Lakes whitefish was composed mainly of these items according to Koelz (1929) and Hart (1931). In lakes of northern Saskatchewan, the actual foods consisted of *Pontoporeia*, fingernail clams, gastropods, chironomid larvae, mayfly nymphs, caddisfly larvae, water boatmen, leeches, water mites, mysids, and cladocerans, the items and proportions varying from lake to lake (Koshinsky 1965; Rawson 1959, 1960).

Small fishes are sometimes found in whitefish stomachs and sometimes fish eggs also. In Lake Erie, as many as five johnny darters have been found in a single whitefish stomach (Scott 1967), alewives in stomachs of

Population			Age (*years*)													
			1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+
		SL														
L. Opeongo, Ont. (Kennedy 1943)	Normal	*inches*	3.1	5.2	6.2	8.6	9.5	9.8	9.9	10.2	10.8	12.4	15.4	14.8	15.9	18.0
		mm	78	133	156	218	242	249	250	258	273	315	391	377	403	456
	Dwarf	*inches*	4.3	4.7	5.0	5.2	5.3	–	–	–	–	–	–	–	–	–
		mm	109	118	128	133	134	–	–	–	–	–	–	–	–	–
		TL														
Cliff L., NW Maine (Fenderson 1964)	Normal	*inches*	7.0	–	10.0	11.0	11.8	12.3	12.9	14.3	15.0	14.6	16.1	18.3	–	–
		mm	178	–	254	279	300	312	328	363	381	371	409	465	–	–
	Dwarf	*inches*	6.4	7.2	7.3	7.4	7.6	–	–	–	–	–	–	–	–	–
		mm	163	183	185	188	193	–	–	–	–	–	–	–	–	–

five whitefish in Lake Huron region (C. A. Lewis, personal communication), the spottail minnow was eaten in Shakespeare Island Lake (Hart 1931), *Leucichthys* sp., ninespine sticklebacks, and *Cottus* sp. in Lake Nipigon (Clemens et al. 1923), ninespine sticklebacks and the deepwater sculpin were reported from whitefish stomachs in northern Saskatchewan (Koshinsky 1965; Rawson 1959), and ninespine sticklebacks were not uncommon in stomachs examined from Beaverlodge and Red Rock lakes, N.W.T. The principal bait used when fishing for whitefish in winter at Lake Simcoe, Ont., is the emerald shiner, either salted or fresh. Feeding by whitefish on eggs of their own and other species has been observed by the following: whitefish eggs (Hart 1931), alewife eggs (Reckahn 1970), cisco eggs (Pritchard 1931; Rawson 1930b).

Small whitefish fall prey to a number of predatory fishes and, in the Great Lakes region, adult whitefish are parasitized by sea lamprey. The effect of sea lamprey predation on Lake Huron whitefish stocks was discussed by Cucin and Regier (1965), who were unable to demonstrate a significant difference in scarring rate of whitefish before and after the application of lampricide in 1961 for lamprey control. The rate of scarring fluctuated around 3% from 1959 to 1964.

The major predators of whitefish are lake trout, northern pike, burbot, yellow walleye, and even whitefish themselves at times when they consume their own eggs. Perch and ciscoes were reported to feed upon larval whitefish in Lake Ontario (Hart 1930), and burbot have been reported to eat whitefish eggs in Manitoba.

The lake whitefish, in addition to having a wide distribution, is also host to many parasite species and consequently there is abundant literature.

Hart (1930) reported the only parasite he found in Bay of Quinte whitefish fry was a glochidium on the pectoral fin of one specimen. Hart (1931) examined 113 adult whitefish from Lake Ontario and found 108 parasitized by tapeworms and hornyhead worms (acanthocephalans), 47 harboured nematodes, and 6 carried crustacean parasites. One whitefish bore a lamprey mark.

The first reported occurrence of *Cystidicola stigmatura* in western Canada was published by Smedley (1933) who found this nematode in the swim bladders of whitefish from many Canadian lakes.

Bangham and Hunter (1939) examined 24 specimens of *C. clupeaformis* from Lake Erie and found 21 infected. Parasites identified were three species of cestodes *Abothrium crassum*, *Schistocephalus* sp., *Proteocephalus exiguus*, the nematode *C. stigmatura*, and acanthocephalans *Echinorhynchus coregoni* and *Echinorhynchus* sp., and one unidentified trematode. All 15 lake whitefish taken from the west end of the lake contained parasites. Six young fish, also taken from the west end of the lake, were infected with the cestode *P. exiguus*; one specimen contained eight larval and one adult form of this cestode.

In Algonquin Park lakes 16 of the 17 whitefish examined by Bangham and Venard (1946) were infected. All contained the cestode *Proteocephalus laruei*. Other parasites were identified as cestodes *Eubothrium salvelini* and *Bothriocephalus* sp.; nematodes *Spinitectus gracilis* and *Rhabdochona* sp.; trematodes *Crepidostomum cooperi* and *C.*

farionis; acanthocephalan *Leptorhynchoides thecatus*; and the copepod, *Ergasilus caeruleus*.

All 99 whitefish which Bangham (1955) examined from Lake Huron carried parasites as follows: cestodes *Proteocephalus exiguus*, *P. laruei*, *Diphyllobothrium* sp., *Cyathocephalus americanus*, and *Triaenophorus crassus*; nematodes *Cystidicola stigmatura*, *S. gracilis*, and *Philometra* sp.; trematodes *Diplostomulum* sp. (highest incidence); acanthocephalan *Echinorhynchus salmonis*; protozoan *Lymphocystis* sp.; and copepod *Achtheres corpulentus*. Details of incidence and localities are provided in Bangham's paper.

A new species of gorgoderid trematode, *Phyllodistomum coregoni*, was described by Dechtiar (1966a) from the ureters and urinary bladder of lake whitefish caught in Lake of the Woods, Ont.

Sandeman and Pippy (1967) and Threlfall and Hanek (1970) reported infection of whitefish by acanthocephalans *Echinorhynchus lateralis* and *Acanthocephalus lateralis* in specimens taken from Mitchell's Pond, Hogan's Pond, and Hugh's Pond in Newfoundland.

The cestode parasite *Triaenophorus crassus* is of particular interest because of the marketing problem caused by the presence of its repulsive cysts in whitefish flesh. Although the cysts are unsightly, they are not harmful to man. The following outline of the life history of *T. crassus* was prepared for us by Dr G. H. Lawler of the Freshwater Institute, Fisheries Research Board of Canada, Winnipeg, where much of the work on *Triaenophorus* has been done.

T. crassus Forel is a pseudophyllidean cestode found typically in the circumpolar subregion of the Holarctic. The northern pike, *Esox lucius*, is the definitive or final host. The parasite attains sexual maturity in the gut of the pike, produces eggs at the time the pike spawns, and then dies. The embryo parasite develops in the egg, becomes a coracidium, and leaves the egg shell. This free-swimming form must be eaten by the first intermediate host, a copepod, for further development. In North America, *Cyclops bicuspidatus* is the most important copepod. In this host the parasite is transformed into a procercoid larva and the duration of this stage may last approximately one month. When an infected copepod is eaten by whitefish, ciscoes, or other members of the family Salmonidae, the procercoid burrows through the gut wall and becomes transformed into a plerocercoid larva which usually encysts in the musculature. This plerocercoid stage may remain viable for 4–5 years and if the infected fish is eaten by a pike during this period the life cycle begins again. It has been found that the degree of infection can be significantly lowered by fishing pike intensively.

Parasitized whitefish are prevented from entering the market by means of restricted fishing in highly infected lakes, rigid inspection of fish, and candling of fillets. For information on candling and associated problems, *see* Budde (1965) and Freese (1970).

Relation to man The lake whitefish is still the most valuable commercial freshwater fish in Canada, although yields have been considerably reduced in recent years because of environmental deterioration and depletion of stocks. Great Lakes landings have been reduced from a high of approximately 17.5 million pounds to a mere 3.5 million pounds in 1969.

The lowered Great Lakes production has encouraged increased yields from northern inland lakes. Even so, the latest yield of 18.3 million pounds for all Canada was the lowest in 20 years and we can expect still lower yields as inland stocks also become depleted.

The total Canadian yield and landed value of lake whitefish for the 5 years, 1964–1968, are presented in the table, p. 276, quantity shown in thousands of pounds and landed value in thousands of dollars. Notice that Manitoba is the heaviest producer, Saskatchewan second, and the Northwest Territories third. As recently as 1948, the Great Lakes alone produced 17.5 million pounds, almost equal the total Canadian production in 1968.

Whitefish are caught commercially in gillnets or trapnets (and, rarely, by hook). In the western provinces, extensive winter fisheries are conducted using gillnets set beneath the ice with the aid of a piece of apparatus called a "jigger" (McKenzie 1947). In days of great abundance in the Great Lakes, they were often seined. In Lake Ontario, Wellington County, in the 1850's, up to 40,000 whitefish could be caught in a single night in the fall using a seine 10 feet deep and 300 feet long.

For decades, Great Lakes whitefish were propagated in the hatcheries and the eyed eggs and larvae released into the lakes in the spring. Investigations into the practice failed to demonstrate its effectiveness and most of the hatcheries have been closed. For a review of this problem, *see* Miller (1946b), Lapworth (1956), Dymond (1957), Christie (1963), and Cucin and Regier (1965).

The lake whitefish is the object of active sport fisheries in many parts of its range, but particularly in inland lakes within the Great Lakes drainage system. Although they can be angled in summer, they are most readily caught in fall and winter and even in spring in some regions. Lake Simcoe has the most productive and best known sport fishery, attracting anglers every season of the year, including summer. Whitefish are caught on a small hook, usually baited with a salted or fresh emerald shiner. Prebaiting (scattering salted minnows or boiled grain on the fishing ground) is common during the winter fishery, which is the most popular. Daily catches of 50–150 whitefish by resident anglers are not uncommon according to MacCrimmon and Skobe (1970) who noted that such anglers may catch a ton or more during the season, which they sell commercially. Catches by tourist or recreational anglers are usually of the order of 1 or 2 fish per hour.

Commercially caught whitefish are sold in the round, headed and dressed, or as fresh and frozen fillets; the commercial categories are "large" (3–4 pounds), and "jumbo" (4 pounds and over), but the most common category is that called "medium" (1.5–3.0 pounds). Canned whitefish, prepared in a small cannery on northwestern Hudson Bay, is a delicious product prepared for the gourmet trade in North American cities.

The exceptionally fine flavour of whitefish has been known and appreciated for centuries. No better attestation can be given than to repeat the quotation of Richardson (1836). "Although we cannot verify that one can eat it for months without tiring, we can say from personal experience that a diet of whitefish

		Year				
		1964	1965	1966	1967	1968
N.B.	*lb*	–	–	2	1	1
	$	–	–	0+	0+	0+
Que.	*lb*	107	101	90	87	39
	$	17	19	18	12	7
Ont.	*lb*	3230	3235	2813	2797	2906
	$	728	784	706	743	917
Man.	*lb*	7283	7454	6035	5642	5289
	$	1090	1159	1002	992	1076
Sask.	*lb*	6121	7607	6498	5388	4750
	$	730	851	827	534	675
Alta.	*lb*	1536	1676	2087	2074	2018
	$	244	315	397	401	445
B.C.	*lb*	–	–	–	–	–
	$	–	–	–	–	–
N.W.T.	*lb*	4467	4011	2807	2435	3208
	$	645	765	552	535	634
Yukon	*lb*	210	152	178	105	89
	$	5	3	5	3	3
Can. Total	*lb*	22,954	24,236	20,510	18,529	18,300
	$	3459	3896	3507	3220	3757

alone, with no other food, can be eaten for days, without losing its appeal." The liver, when cooked, is also of fine flavour and texture and can be made into an excellent paté. Whitefish eggs, when properly prepared, are sometimes marketed as caviar.

Nomenclature

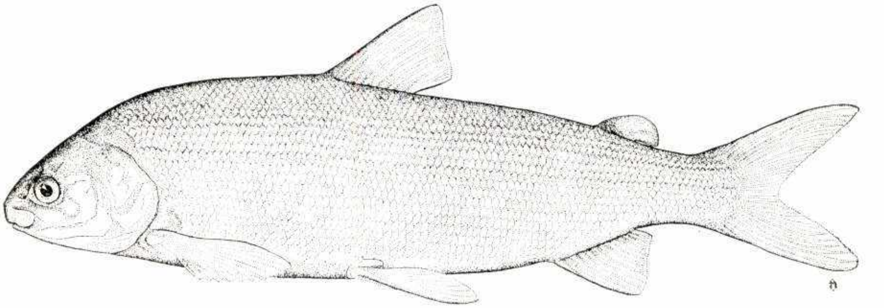
Salmo clupeaformis	— Mitchill 1818a: 321 (type locality Falls of St. Mary, northern extremity of Lake Huron)
Coregonus albus	— LeSueur 1818a: 232
	— Perley 1852: 204
Salmo (Coregonus) Labradoricus (Richardson)	— Richardson 1836: 206
Coregonus clupeiformis DeKay	— Agassiz 1850: 339
Coregonus sapidissimus Agass.	— Agassiz 1850: 344
Coregonus latior Agass.	— Agassiz 1850: 348
Coregonus clupeiformis (Mitchill)	— Evermann and Smith 1896: 297
Coregonus labradoricus Richardson	— Evermann and Smith 1896: 302
	— Cox 1896b: 67
Coregonus clupeaformis Mitchill	— Jordan and Evermann 1911: 35
Coregonus odonoghuei	— Dymond 1943: 228
Coregonus atikameg	— Dymond 1943: 228
Coregonus nelsonii Bean	— Dymond 1943: 228
Coregonus kennicotti Bean	— Dymond 1943: 228

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *clupeaformis* — herring-shaped.

Common names Lake whitefish, common whitefish, Sault whitefish, whitefish, eastern whitefish, Great Lakes whitefish, inland whitefish, gizzard fish. French common name: *grande corégone*.

BROAD WHITEFISH

Coregonus nasus (Pallas)



Description Body elongate, thick and heavy set, less streamlined or tapered than *C. clupeaformis*, average total length about 18 inches (457 mm), compressed laterally, greatest body depth in front of dorsal fin. Head deep, wide and short, its length 18–23% of total length; eye small; mouth inferior, distinctly overhung by snout, maxillary extending posteriorly scarcely to below anterior margin of eye, but sometimes beyond margin, maxilla length 19–23% of head length; weak teeth on lingual plate. Gill rakers total range 18–25, length of longest gill raker 13–19% of inter-orbital width. Branchiostegal rays 8 or 9. Fins: dorsal adipose present, sometimes large and conspicuous; dorsal 1, rays 10–13; caudal distinctly forked; anal rays 11–14; pelvic rays 11 or 12, pelvic axillary process present; pectoral rays 16 or 17. Scales cycloid, large, 84–102 in lateral line. Pyloric caeca about 148. Vertebrae 60(3), 62(5), 63(1).

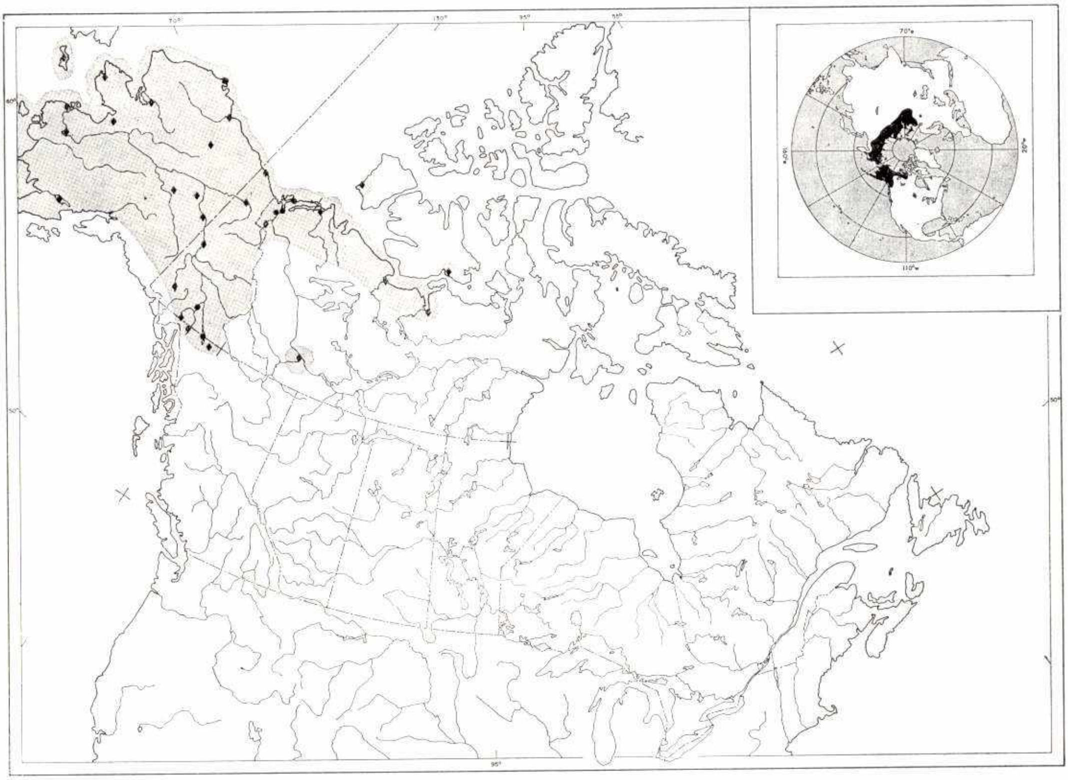
Nuptial tubercles or pearl organs developed on scales on flanks of breeding males, smaller and fewer on females.

See also Lindsey (1962) and McPhail and Lindsey (1970), the latter the source for some data given above.

Colour Overall colouration silvery with a greyish cast, sometimes with light brown tinge enhanced by darkened scale margins; back olive-brown to black, silvery on sides and silvery white below, sometimes yellowish. Cheeks and opercles often with brown, freckle-like spots. Fins of adults smoky or pearl grey, sometimes darker and more or less opaque, pelvics usually lighter; pectoral, and sometimes anal, with bluish or purplish iridescence; fins light on young or immature specimens.

Systematic notes The broad whitefish was described by Pallas (1776) based on specimens from the Bay of Ob, USSR. The first description of the North American form under the name *Coregonus kennicotti*, is credited to Milner, in Jordan and Gilbert (1883). Since 1871 (Dall) the nomenclature for the species has been most confused. Dymond (1943) erroneously synonymized *C. kennicotti* and *C. clupeaformis*; and in 1957, Svärdson expressed the view that the North American *C. clupeaformis* was a synonym of the Eurasian *C. nasus*, a view expressed previously by Dymond (1943).

Fortunately, the numerous collections made in the Northwest Territories by the Fisheries Research Board of Canada in 1959 were available to Lindsey (1962) who presented a thorough systematic review of the broad whitefish in North America. He demonstrated the distinctness of *C. nasus* from *C. clupeaformis* by using such characters as gill raker length plotted against interorbital width, dorsal profile of head, and other characters. Gill raker counts alone are not diagnostic. Few biologists who have had the



opportunity of working with both species in the field would be likely to confuse them. For a thorough discussion of the systematics and relationships of this species, *see* Lindsey (1962).

Distribution The broad whitefish is distributed in the fresh and brackish waters of the arctic drainages of northwestern North America and northern Eurasia, south to about the 60th parallel. The western limit of range is the Pechora River, USSR, just west of the Ural Mountains, from which it occurs east, to the Bering Sea. In North America, it occurs from the Perry River, N.W.T., west in numerous river systems of arctic Canada (such as the Coppermine, Mackenzie, and the headwaters of the Yukon River, including Teslin Lake, B.C.), and offshore only to Herschel Island in Beaufort Sea, to the Kuskokwim River, Bering Sea drainage, Alaska. As has been amply demonstrated by Lindsey (1962), it is *not* found in Great Bear Lake.

Biology The biology of the broad whitefish is not well known, partly because of confused taxonomy but, also, because of its northern distribution. Much of the following information was taken from Wynne-Edwards (1952), whose observations on northern fishes have been exceptionally valuable. He noted that it spawned in rivers in July and August, somewhat earlier than the humpback whitefish (*C. clupeaformis*). McPhail and Lindsey (1970) noted, however, that a specimen taken in the Yukon River, near Dawson City, on October 4, had tubercles and well-developed eggs. In the Mackenzie, at Arctic Red River, females outnumbered males by 12–15 to 1. The eggs are large and are pale yellow in contrast to the orange-yellow eggs of the humpback. The downstream migration of spawners may occur in midwinter Wynne-Edwards noted, "since there was formerly an important winter fishery for broad whitefish about Minto and Pelly Crossing in the Yukon Territory."

No growth studies of Canadian populations are available, but in the Yenisei River, Siberia, the broad whitefish matures at about age 7 and lives to 15 years and older (Nikol'skii 1954). It is believed to grow larger than the humpback whitefish (*C. clupeaformis*) at least in the lower Mackenzie, where the broad whitefish is said to attain weights of over 4 pounds (2 kg) (Wynne-Edwards 1952). It is said to attain weight of 30.6 pounds (16 kg) in the Kolyma River, Siberia.

It is found more frequently in rivers than lakes and is occasionally taken in brackish waters. In Siberia, Nikol'skii noted that it overwintered in river channels and large lakes.

Its food is said to consist of bottom organisms, such as aquatic insect larvae, small molluscs, and crustaceans.

No list of parasites of broad whitefish in Canadian waters has been published. A summary of parasites occurring in USSR specimens was compiled by Bykovskaya-Pavlovskaya et al. (1962) and included by Lawler (1970).

Relation to man In the northwest, the broad whitefish is taken by gillnet for local consumption only, for use as both human and dog food. It is an esteemed food fish and the white flesh is delicately flavoured. It is eaten fresh but is also preserved by splitting and air-drying or smoking.

For further information *see also* Wynne-Edwards (1947, 1952) and McPhail and Lindsey (1970).

Nomenclature

Salmo (Coregonus) nasus	— Pallas 1776: 705 (type locality Bay of Ob, USSR)
Coregonus nasus	— Günther 1866: 177
	— Dymond 1943: 192
Coregonus kennicotti	— Milner *in* Jordan and Gilbert 1883a: 298
Coregonus nasus kennicotti	— Wynne-Edwards 1952: 13
Coregonus nasus kennicotti Milner	— Cohen 1954: 169
Coregonus nasus (Pallas)	— Walters 1955: 281

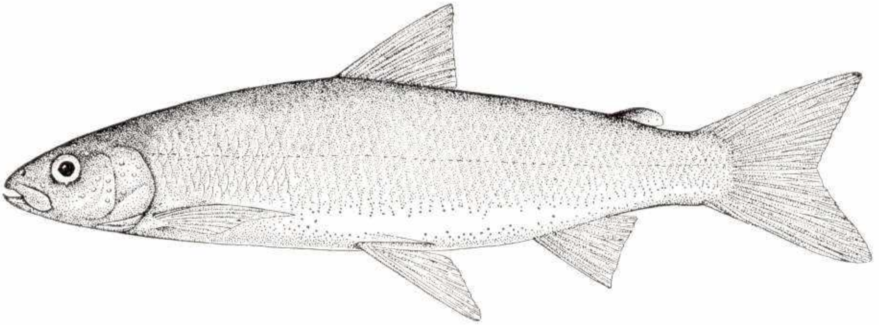
(*See* also Lindsey (1962) for a detailed discussion of the nomenclature.)

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *nasus* — referring to shape of nose.

Common names Broad whitefish, round-nosed whitefish, sheep-nosed whitefish, khlugu-zhey, tezareh, tezra. French common name: *corégone tschir*.

ATLANTIC WHITEFISH

Coregonus canadensis Scott



Description Body elongate and terete, average length to about 15 inches (381 mm), compressed laterally but less so than lake whitefish, greatest body depth at front of dorsal fin 18–22% of total length. Head relatively short, about 20% of total length, never observed to have nuchal hump; eye small, its diameter 17–24% of total length, adipose eyelid distinct; snout length 25–28% of head length, always greater than eye diameter; mouth usually terminal and upper and lower jaws equal on small or medium-sized fish when mouth closed, upper jaw or snout projecting slightly on large males, maxillary extending to below anterior part of eye, seldom to below pupil, maxilla length 25–30% of head length; small but well-developed teeth present on premaxillaries, vomer, palatines, dentary, and tongue at all ages. Gill rakers, extreme range 23–27, usually 25 or 26, length of longest gill raker 23–50% of interorbital width. Branchiostegal rays 6–9. Fins: dorsal adipose present; dorsal 1, rays 10–12; caudal distinctly forked; anal rays 9–12; pelvic rays 11 or 12, pelvic axillary process long, exceeding maxillary length at all ages; pectoral rays 15 or 16. Scales cycloid, moderately large, 91–100 in lateral line. Vertebrae 63 or 64.

Nuptial tubercles or pearl organs developed on males at least, on scales on flanks and also on top (few) and sides of head.

Colour Overall colouration silvery; dark blue to dark green on the back, becoming silvery on the sides and silvery white below. Dorsal and caudal fins dusky, lower fins light.

Distribution Restricted to Nova Scotia, where it is known to occur in Millipsigate Lake, (and possibly other nearby lakes) and also in the Tusket River system. In the latter, there was a regular downstream and upstream movement, and some whitefish at least moved out of the estuary into fully salt water. Some specimens were caught in Yarmouth Harbour.

Biology We know little about the biology of this whitefish. It is fairly certain that the Tusket River population was anadromous for there was said to be a definite and regular upstream migration, (a spawning run?) in October. The species grows to a length of at least 20 inches (508 mm).

Stomach contents of specimens taken in Yarmouth Harbour yielded amphipods, small periwinkles (*Littorina littorea*), and marine worms. It is assumed that Millipsigate Lake specimens ate aquatic insect larvae and other invertebrates.

Relation to man Interviews with local residents indicate that prior to 1965, the

Tusket River population was ruthlessly exploited during the upstream movement in October. The building of a hydro-electric dam and the installation of a fish ladder, which was not supervised, exposed the migrating fish to easy capture by poachers with dipnets. The Tusket River population appears to be seriously depleted.

Nomenclature

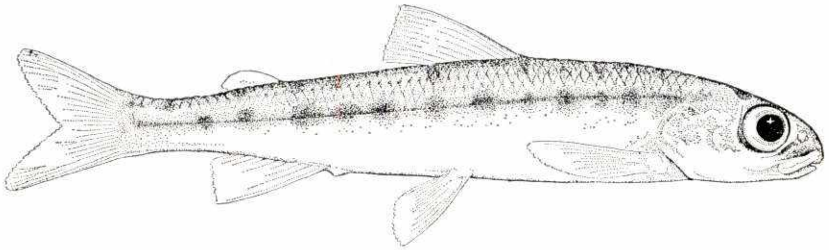
Coregonus labradoricus Richardson	— Piers 1927: 92
Coregonus clupeaformis (Mitchill)	— Dymond 1947: 8
Coregonus sp.	— Leim and Scott 1966: 104
Coregonus canadensis	— Scott 1967: 26

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *canadensis* — in reference to Canada, the only place it occurs.

Common names Atlantic whitefish, whitefish, Sault whitefish. French common name: *cisco*.

PYGMY WHITEFISH

Prosopium coulteri (Eigenmann and Eigenmann)



Description Body elongate, about 4–5 inches (102–127 mm) total length, almost cylindrical, body depth less than twice body width, and, hence, body only slightly compressed laterally except in region of caudal peduncle, females deeper bodied than males. Head elongate, its length slightly greater than body depth; eye relatively large, its diameter greater than snout length; snout bluntly rounded, overhanging mouth, not as obviously pointed as in *P. cylindraceum*, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly from anterior edge of orbit to centre of eye; teeth small, restricted to tongue, absent from jaws, vomer, and palatines. Gill rakers short, 6.5–8.8% of head length, total count, 11–21, upper limb of gill arch 3–7, lower limb 8–13, but McCart (1970) studied many samples and recorded a range of 12–21. Branchiostegal rays 6–9 + 6–9 (McPhail and Lindsey 1970), but 7+7(3), 8+7(1), 8+8(6), in Lake Superior. Fins: Eschmeyer and Bailey

(1955) noted that on mature fish rayed fins always larger on males than females; small adipose dorsal present; dorsal 1, 10–12 rays; caudal distinctly forked; anal rays 10–14; pelvic rays 9–11, axillary process present; pectoral rays 13–18, axillary process absent. Scales cycloid, large; lateral line complete, 50–70 pored scales. Pyloric caecae simple, low in number, 13–33. Vertebrae 50–55 (McPhail and Lindsey 1970) but in Lake Superior 52(2), 53(7), 54(1) (Eschmeyer and Bailey 1955).

Nuptial tubercles developed on both males and females, more conspicuous on males, and occur on top of head, on scales on back and sides, and on paired fins.

For additional morphometric and meristic data *see* section on *Systematic notes* and *also* Eschmeyer and Bailey (1955) and McCart (1970).

Colour Brownish above, silvery on the sides and white below. Dorsal, caudal, and pectoral fins usually clear, anal and pelvic whitish and immaculate, a faint dark spot sometimes present on base of caudal fin. A series of 12–14 similar spots along midline of back, and 7–14 dark, round or oval parr marks with diffuse borders along lateral line of young and subadults, usually vague or absent on adults, although some Alaskan forms retain parr marks even on largest fish (McCart 1970). The use of the term "parr marks" may be misleading but *see* comments on colour of *Prosopium cylindraceum*.

Systematic notes This rather well-defined species was poorly known until quite recently. Although once thought to be rare, it is now known to be more common than formerly supposed (McCart 1965). Still puzzling, however, are the peculiarly isolated Lake Superior populations. It might be, as suggested by McPhail and Lindsey (1970), that this small species is present in intervening lakes but has not been collected. The Lake Superior populations were not detected until 1952 when a bottom trawl was fished at depths over 60 feet (18.3 m).

The existence of sibling species of pygmy whitefish was discussed by McCart (1970), who presented evidence of sympatric populations of low gill raker forms and high gill raker forms in Alaskan lakes. Such evidence was not available to Eschmeyer and Bailey (1955), who concluded that the differences between widely separated populations was slight. Evidence available to date, especially that presented by McCart (1970), suggests that the Lake Superior population is sufficiently divergent from western populations to have had a Mississippian glacial refugium, while western populations may have redispersed from a Yukon–Bering Sea refugium (high gill raker form), or a western refugium south of the ice sheet (low gill raker form).

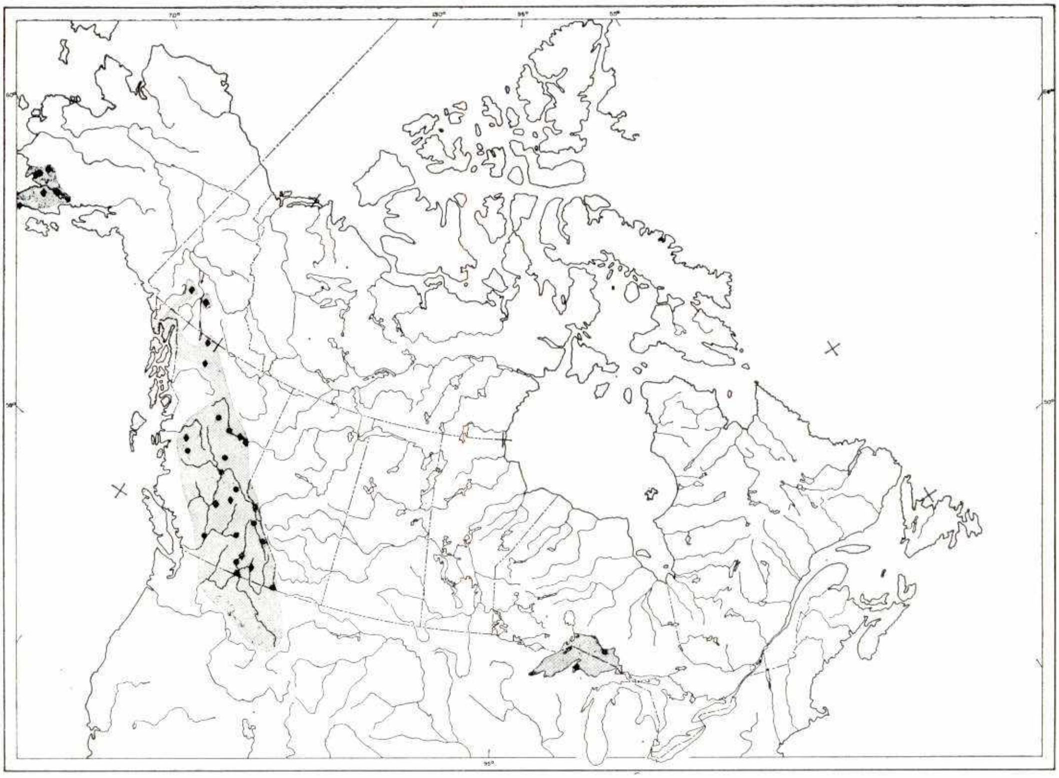
For additional information, *see* Eschmeyer and Bailey (1955), McCart (1965, 1970), Heard and Hartman (1966), and McPhail and Lindsey (1970).

Distribution The pygmy whitefish has a disjunct or discontinuous distribution in North America. It occurs in the Columbia River system in western Montana and Washington, in British Columbia, Yukon Territory, and in the Bristol Bay and Alaska Peninsula region of southwestern Alaska.

In Canada, it occurs in the Columbia, Fraser, Skeena, Peace, and Liard River systems in British Columbia, and in the upper Yukon River system (Teslin River) and Alsek River system in British Columbia and Yukon Territories. In the east, it occurs in Lake Superior where its presence went undetected until 1952.

Biology Information on spawning is meagre but available evidence suggests that it usually takes place in October, November, or December, depending on the region. Indirect evidence gathered by McCart (1965) in British Columbia lakes suggested spawning occurred in October or November. In Bull Lake, Mont., spawning occurred in December and January in 1952–1953, and in Lake Superior, the capture of unripe fish in October and spent fish in January, indicated November–December spawning.

Spawning is assumed to take place in shallow water, in streams or lakes. The eggs are



probably scattered over coarse gravel and develop over winter emerging from gravel in early spring. The eggs, large when ripe, measured 2.0 mm in diameter in specimens from Lake Superior and 2.4 mm in specimens from the Naknek River system in Alaska. A female of 5.1 inches (130 mm) total length from Lake Superior averaged about 440 eggs while a female of the same length from Naknek River system averaged 580 eggs (Heard and Hartman 1966).

Growth is slow and the maximum size attained is small. Females grow faster and live longer than males. In Maclure Lake, B.C., females live longer than elsewhere, attain an age of 9 years, and a fork length of 10.7 inches (271 mm), whereas males reach 6 years of age and a fork length of 8.8 inches

			Age (*years*)								
			1+	2+	3+	4+	5+	6+	7+	8+	9+
Keweenaw Bay, L. Superior	TL *inches*	M	3.0	3.7	4.0	4.2	4.3	–	–	–	–
		F	3.0	4.0	4.2	4.7	5.0	5.0	5.0	–	–
(Eschmeyer and Bailey 1955)	*mm*	M	76	94	102	107	109	–	–	–	–
		F	76	102	107	119	127	127	137	–	–
Cluculz L., B.C. (McCart 1965)	FL *inches*	M	–	3.6	4.5	4.6	4.6	4.8	–	–	–
		F	–	3.2	4.3	4.8	5.0	5.6	6.2	–	–
	mm	M	–	92	113	116	116	122	–	–	–
		F	–	81	110	121	127	142	156	–	–
Maclure L., B.C. (McCart 1965)	FL *inches*	M	–	4.8	7.6	8.3	7.3	8.9	–	–	–
		F	–	4.6	7.5	8.6	9.6	9.8	10.1	–	10.7
	mm	M	–	121	192	210	185	225	–	–	–
		F	–	117	190	219	245	248	257	–	271

(225 mm). A table of comparative lengths at various ages appears on p. 284.

In Lake Superior the pygmy whitefish is a deepwater species, with a depth range of from 60–294 feet (18.3–88.6 m), but the largest catches are made at 180–234 feet (54.9–70.3 m). There is no change in depth distribution with season. In the Pacific drainage, this whitefish thrives in lakes and the flowing waters of clear or silted rivers of mountainous country. In western lakes, it lives in shallower water than in Lake Superior, but usually deeper than 20 feet, although it may also occur in shallows.

The pygmy whitefish is apparently quite adaptable in feeding habits. Crustaceans and aquatic insect larvae, especially chironomids, are the primary foods. In Lake Superior, ostracods and *Pontoporeia*, are principal crustaceans eaten but copepods are important in diet of young fish. In Alaskan lakes, chironomids were also important but, in addition, plecopteran larvae were consumed and planktonic crustaceans were also significant in the diet. In both Lake Superior and Alaskan lakes, fish eggs were eaten, and it is probable they are important in the diet. In Alaska the eggs appeared to be salmon eggs, in Lake Superior, coregonine eggs. *See* Eschmeyer and Bailey (1955) and Heard and Hartman (1966) for further information.

Predation on pygmy whitefish is poorly documented. They were reported to be caught by kingfishers at the surface of a lake in Washington (Snyder 1917) and terns (*Sterna paradisaea*) were observed to be catching presumed pygmy whitefish at the surface of a lake in the Naknek River system in Alaska (Heard and Hartman 1966).

Apparently the parasites associated with the pygmy whitefish have not yet been reported.

Relation to man It is of no known direct economic importance, and its indirect importance as a forage species, for example, in Lake Superior, is unknown, but it is eaten by arctic char and Dolly Varden in the northwest.

Elsewhere, when abundant, as in some Alaskan lakes, it may compete for food with young sockeye salmon, or may act as a buffer between salmon predators and young salmon (Heard and Hartman 1966).

The remarkably discontinuous distribution pattern and systematic variation provide data of especial interest to students of North American zoogeography and postglacial dispersion.

Nomenclature

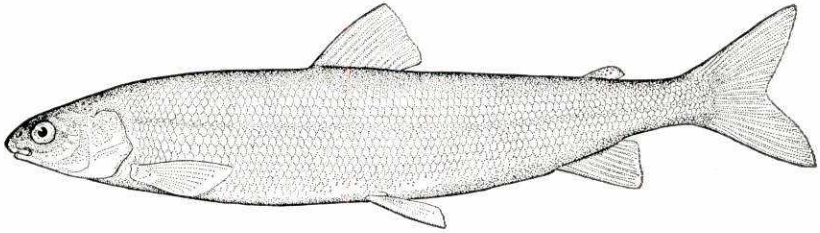
Coregonus coulterii E. and E.	— Eigenmann and Eigenmann 1892: 961 (type locality Kicking Horse River at Field, B.C.)
Coregonus coulteri Eigenmann and Eigenmann	— Eigenmann 1895: 115
Prosopium Milner	— Hubbs 1926: 13
Prosopium coulteri (Eigenmann and Eigenmann)	— Jordan, Evermann, and Clark 1930: 65
Prosopium snyderi	— Myers 1932: 62
Prosopium coulterii (Eigenmann and Eigenmann)	— Dymond 1947: 8

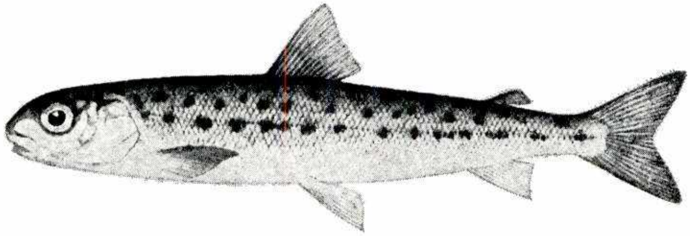
Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *coulteri* — after Dr J. M. Coulter, a distinguished botanist.

Common names Pygmy whitefish, Coulter's whitefish, brownback whitefish. French common name: *ménomini pygmée.*

ROUND WHITEFISH

Prosopium cylindraceum (Pallas)

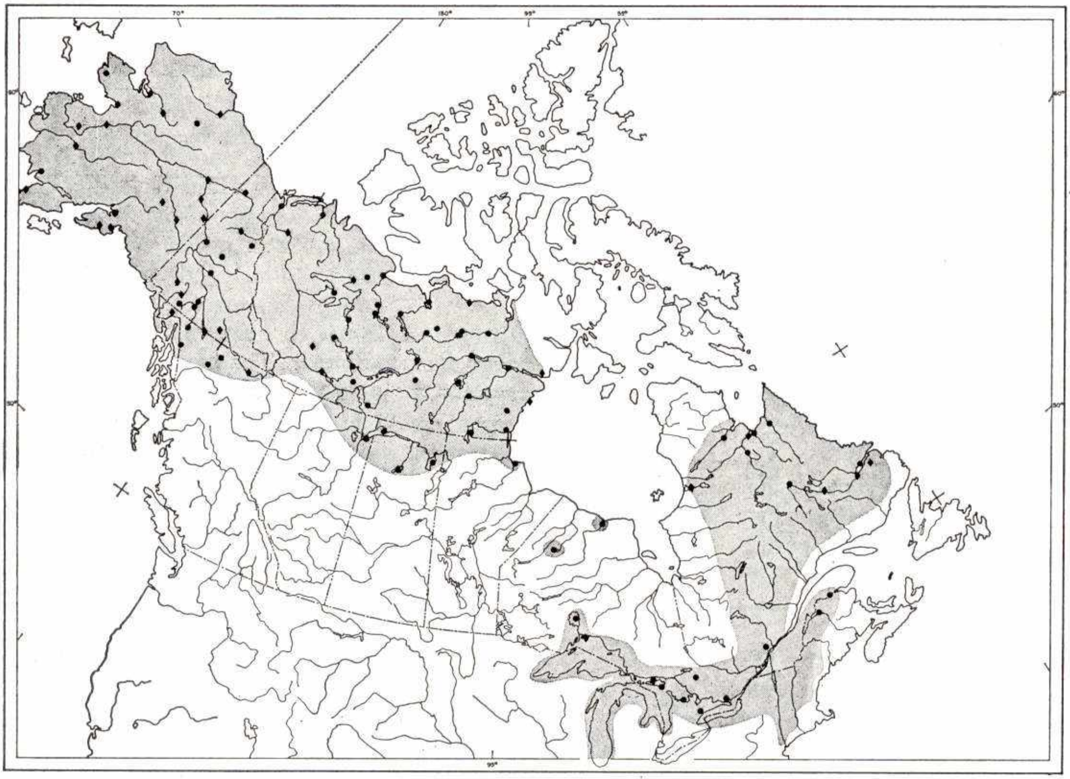




Description Body slender, elongate, average length about 8–12 inches (203–305 mm), almost cylindrical in cross section, greatest depth in front of dorsal fin, posteriorly body somewhat compressed laterally. Head relatively short, its length about 20% of total length; eye moderate, its diameter less than snout length; snout pointed, "pinched" or compressed laterally, rounded in lateral view, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly almost to anterior margin of eye of adults; teeth small, restricted to a small central patch on tongue, and on bases of gill rakers, but absent from jaws, vomer, and palatines. Gill rakers short, total range 14–21, upper limb of gill arch 5–8, lower limb 9–13, usually 15–17 in Great Lakes region, 17–21 in Northwest Territories, gill rakers with teeth at bases (Norden 1970). Branchiostegal rays 6–9 + 7–9, commonly 7+7 to 8+8. Fins: small adipose dorsal present, dorsal 1, with 11–15 rays; caudal distinctly forked; anal rays 10–13; pelvic abdominal, 9–11 rays, a pelvic axillary process present; pectoral rays 14–17, no pectoral axillary process. Scales cycloid, large, those on back outlined with dark pigment; lateral line complete, scales variable, ranging from 74–108 over whole range (*see* Walters 1955, who gave table of comparative counts with total range of 74–106 scales). Pyloric caecae variable, range 50 (Lake Ontario) to 130 (Northwest Territories). Vertebrae 58–65 over whole range but in Lake Huron 62(6), or 63(3), in Northwest Territories 62(1), 63(7), 64(1).

Nuptial tubercles (based on observations on specimens caught in Owen Channel, Lake Huron, November 9–10, 1958) well developed on males, less so on females, one tubercle per scale, located on centre of exposed field of scale for first 5 rows of scales above and below lateral line; a few smaller tubercles on nape, none on head.

Colour The round whitefish has more colour than most coregonids. Overall colouration of adults almost silvery but back sepia brown or almost bronze, with green tinge, sides silvery, silvery white below. Scales, especially on back, with well-defined, dark, pigmented borders, making them conspicuous. Pectoral fins are amber in colour, slight amber tint also to pelvic and anal fins. Pectorals take on an orange tint during spawning, pelvic and anal fins also, to a lesser extent. A light dusting of black pigment may occur on



dorsal and caudal, very lightly on margin of anal, and on dorsal surface of pelvic and pectoral fins. The adipose is usually brown spotted, particularly on specimens in central and eastern Canada.

Young are silvery with two or more longitudinal rows of black spots on sides. Compare illustrations of adult (*above*) and young (*below*) on p. 286. The conspicuous lower row of 10 or more spots occurs along the lateral line; just below the midline of the back is a series of 10 or more spots that may coalesce with spots across the back. Between these two rows is a series of marks or pigmentation concentrations of variable sizes, not always recognizable as spots.

Black spots on midline of sides are most intense at lengths of 2–3 inches (51–76 mm), but may be visible on dead specimens up to 10.5 inches (267 mm) long. They are sometimes called parr marks but this word is perhaps somewhat misleading when applied to *P. cylindraceum*, for the marks are round, or, at most, longitudinally ovoid, and much less ventrally ovoid than in chars, *Salvelinus* spp., or related species.

Systematic notes McPhail and Lindsey (1970) remarked upon the apparent discontinuity of the Canadian distribution in the vicinity of the Manitoba–Ontario border, and the possible existence of two morphological types. The northwestern populations were said to have high mean gill raker counts (17.8–19.2) and high pyloric caeca counts (94.1–106.2) while eastern populations have low gill raker counts (16 or 17) and pyloric caeca (67.6–82.8). These authors theorize that the differences have resulted from postglacial dispersion from two refugia rather than from environmental differences, since clinal variation cannot be demonstrated. Available evidence suggests that vertebrae numbers exhibit the same trend as gill rakers and pyloric caecae.

Distribution The round whitefish ranges widely through northern North

America and into northeastern Asia, where it is found from the Yenisei River to Bering Strait and Kamchatka Peninsula. In North America, it is found in a single lake in Connecticut, (East Twin Lake), from the New England states and from Labrador on the east, to Alaska in the northwest.

In Canada it ranges from northern New Brunswick, Labrador, and Ungava west through parts of Quebec, Ontario, and the Great Lakes, including Lake Nipigon but excluding Lake Erie. Farther north in Ontario it has been reported from the mouth of the Winisk River and Big Trout Lake.

The distribution is discontinuous in the general region of the Ontario–Manitoba border. Thence, from northern Manitoba the species is distributed northwestward through the Territories and northern British Columbia to Alaska.

Biology Spawning takes place in the fall of the year in the gravelly shallows of lakes, at river mouths or, on occasion, in rivers. It usually occurs in November in the Great Lakes region and earlier northward. In lakes Michigan and Huron, Koelz (1929) established that round whitefish spawned in November, over gravel, at depths of 12–48 feet. In Lake Superior, experimental fishing in 1960 indicated spawning took place in late November and early December over a gravel and rock bottom at a depth of 21 feet and a temperature of 40° F (4.5° C). Near Nueltin Lake, on the border of Manitoba and the Northwest Territories, an upstream spawning migration was noted in late October (Harper 1948). In New Hampshire, fish began arriving on the spawning grounds during the last two weeks of November (Normandeau 1969) and the peak of spawning activity occurred about the second week of December. Males usually arrive on spawning grounds before females, but neither males nor females eat during prespawning or spawning activities. Normandeau noted that the fish swam in pairs during spawning and did not form large spawning schools. In common with other whitefish, no parental care is given eggs or young.

The eggs are orange in colour and are large for a coregonid. In New Hampshire, unfertilized ova ranged in diameter from 2.4–2.9 mm and, after a few hours in water, attained maximum diameters, ranging from 3.3–4.6 mm. The number of eggs deposited by spawning females is not known but fecundity for Lake Superior fish was estimated by Bailey (1963). The number of eggs in ovaries of females ranging in total length from 12–17 inches (305–432 mm) increased from an average of 2461 for the smaller size to 10,459 for the larger. The largest number of eggs for a single female was 11,888. Using data from 37 females, Bailey calculated an average production of 341 eggs per ounce of fish. Normandeau observed and collected newly hatched fry on March 31, 1962, but considered that the peak of hatching occurred during the last week of April, and that all were hatched by May 11. He calculated that 140 days at 36° F (2.2° C) was, therefore, required for development, considering that the peak of spawning occurred about the end of the first week of December. This figure of 140 days to hatching is similar to the time to hatching required by lake whitefish as described by Hart (1930).

In common with other coregonine fishes, the age of individuals can be determined by examining the scales. The lengths at various ages for a number of populations are shown in the accompanying table. Note that length is sometimes given as fork length, at other times as tip length. The growth rate in Lake Michigan is obviously much higher than in Canadian lakes, particularly in the Ungava region. Great Slave Lake growth rates, however, are remarkably good and are higher than those for Lake Superior. The maximum size is probably 22.1 inches (561 mm) total length, a 13-year-old fish from Great Slave Lake. Keleher (1961) listed a 4.5-pound specimen, 508 mm fork length. Koelz (1929) gave a maximum size for Lake Superior of "about 5 pounds" but provided no further details.

In the more southerly parts of its range, the round whitefish is usually found in deep lakes, although it is not known to inhabit the deeper waters regularly. In the Great Lakes,

		Age (*years*)													
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+
	FL														
Ungava (Koksoak R.)	*inches*	–	6.0	6.9	7.9	8.7	9.5	10.5	11.6	12.0	12.6	13.9	14.6	–	–
(Mackay and Power 1968)	*mm*	–	152	175	201	221	241	266	294	305	320	352	370	–	–
	TL														
Great Slave L., N.W.T.	*inches*	3.5	7.0	11.2	10.5	13.4	14.6	15.8	17.4	18 4	20.6	–	20.1	22.1	20.2
(Rawson 1951)	*mm*	89	178	284	267	340	371	401	442	467	523	–	511	561	513
	FL														
Great Bear L., N.W.T.	*inches*	–	–	–	–	12.9	13.3	13.9	14.5	16.6	–	–	–	–	–
(Kennedy 1949b)	*mm*	–	–	–	–	328	338	353	368	421	–	–	–	–	–
	Wt (*oz*)	–	–	–	–	14	14	16	19	32	–	–	–	–	–
	TL														
L. Michigan	*inches*	–	12.2	14.2	15.5	17.4	18.3	19.6	–	–	–	–	–	–	–
(Mraz 1964b)	*mm*	–	310	361	394	442	465	498	–	–	–	–	–	–	–
	TL														
Apostle Is., L. Superior	*inches*	4.3	7.1	9.0	10.7	12.0	13.0	14.0	15.0	15.5	–	–	–	–	–
(Bailey 1963)	*mm*	109	180	229	272	305	330	356	381	394	–	–	–	–	–

Lengths calculated to exactly *n* years, rather than *n*+ years.

Koelz (1929) considered it to be a shallow-water species, inhabiting water less than 150 feet (45.7 m) deep. More recent investigations in the Great Lakes support this view and Dryer (1966) noted that in western Lake Superior it was most abundant at depths less than 120 feet (36.6 m), and that none were caught at depths greater than 236 feet (71.9 m). However, in August, 1959, the United States Fish and Wildlife vessel M/V *Cisco* caught a single round whitefish in bottom gillnets set in 600 feet (218.9 m) in eastern Lake Superior off Grand Marais, Mich., the greatest depth recorded for the species.

In the northerly parts of its range and elsewhere, such as Quebec and New Brunswick, round whitefish may be found in rivers or streams. It has been reported in brackish water on both sides of Hudson Bay (Dymond 1933; McAllister 1964b) and off the mouths of the Coppermine and Mackenzie rivers, although Backus (1957) remarked on its absence in brackish waters in Labrador.

This bottom-feeding whitefish eats a variety of benthic invertebrates, especially mayfly larvae and pupae, caddisfly and chironomid larvae, and small molluscs such as fingernail clams and snails. Such food items as these have been reported from inland lake populations across Canada but, in addition, Rawson (1959) noted crustaceans *Hyalella* and the remains of a small fish in stomachs from Saskatchewan's Cree Lake. Fish was also reported in stomachs of samples caught in July in Atlin Lake in northern British Columbia (Withler 1956).

A comprehensive study of food was carried out in Algonquin Park lakes by Sandercock (1964), who remarked on the apparent competition for food between round and lake whitefish and on the depressed growth rate of *P. cylindraceum* when *Coregonus clupeaformis* was present. The lower growth rate was attributed to the greater efficiency by *C. clupeaformis* in procuring planktonic organisms for food.

The species is also known or at least suspected to feed on the eggs of other fishes, such as lake trout (Loftus 1958). Martin (1957) expressed the view that round whitefish may have been a serious predator on lake trout eggs in Lake Opeongo, but had no direct evidence. In Lake Ontario, Hart (1930) reported finding 30 lake trout eggs in one round whitefish stomach, but no lake whitefish eggs. During exploratory fishing activities by the United States Fish and Wildlife Service in Lake Superior in November and December, 1958, a large number of round whitefish were examined for possible predation on lake whitefish eggs but only one round whitefish had eaten eggs and these were possibly round whitefish eggs. Harper (1961) reported fish, presumed to be round whitefish, present on longnose sucker spawning grounds in Labrador. Its reputation in former years for "waiting on" shad (whence the name "shad waiter") and then eating their eggs in one or two New Hampshire lakes was reviewed by Harper.

Lake trout are known to prey upon round whitefish (Dymond 1928b; Martin 1957; Harper 1961) but usually not as a major item of diet. Other than the above casual observation of trout stomachs, Normandeau (1969) who worked on Newfound Lake, N.H., provided one of the few accounts of predation on the species. Brown bullheads and burbot consumed eggs on the spawning grounds, and yellow perch and white suckers were also presumed to have fed on eggs. Yellow perch are known to be serious predators on eggs of lake whitefish and it is probable that they are also significant predators on those of round whitefish, since the two whitefishes utilize similar types of spawning grounds. In Newfound Lake, Normandeau found spent female round whitefish were also feeding on eggs. The same author noted that predation on newly hatched fry may be heavy. In May, he examined two Atlantic salmon, *Salmo salar*, that had over 200 fry in their stomachs. From the same lake, a 10-inch (254-mm) round whitefish was found in the stomach of a chain pickerel, *Esox niger*.

The round whitefish appears to support a rather large parasite fauna. All specimens examined by Bangham (1941) and Bangham and Venard (1946) from Lake Opeongo, Algonquin Park, Ont., were infected. Parasites identified were trematodes *Crepidostomum farionis* and *C. cooperi*, copepods *Ergasilus caeruleus* and *E.* sp., nematode *Spinitectus gracilis*, and the acanthocephalan *Leptorhynchoides thecatus*. Bangham (1955) examined 22 specimens from Lake Huron and Manitoulin Island and found all infected. A total of 10 parasite species were recorded, and two of the whitefish represented a new host for the acanthocephalan *Neoechinorhynchus tumidus*.

An important parasite of most coregonine fishes, including this species, is the cestode, *Triaenophorus crassus*, which infects members of northwestern populations (Lawler and Scott 1954). For additional information on *Triaenophorus see* account in *Coregonus clupeaformis*.

See also Bangham and Adams (1954) for a list of parasites attacking the species in British Columbia waters, and Hoffman's (1967) checklist of parasites of this whitefish in North American fresh waters.

Relation to man The flesh is of fine quality and it is usually highly regarded as a food fish by the relatively few who have eaten it. It is sought by anglers to a limited extent in the rivers and streams of northwestern New Brunswick.

It is of minor commercial importance in Canada largely because of small average size and fluctuating supply. Commercial landings between 1960 and 1968 from Ontario waters, principally Lake Huron and Lake Superior, under the name "menominee," fluctuated from 20,000 to 70,000 pounds and were valued at \$1500 to \$10,000. It supported a larger fishery in United States Great Lakes waters in past years. Bailey (1963) reported annual yields of upwards of 250,000 pounds in Lake Michigan, and 100,000 pounds in United States waters of Lake Huron.

Round whitefish are known to eat the eggs of other fishes, lake trout in particular, but in turn its eggs and young are preyed upon by other species and itself is eaten by lake trout. It was considered an important forage fish for lake trout in Maine by Everhart (1958) and in Great Slave Lake by Rawson (1947).

Nomenclature

Salmo Cylindraceus	— Pallas (*in* Pennant 1784: ciii-civ) (type locality Lena, Kowyma, and Indigirska rivers)
Coregonus quadrilateralis	— Richardson 1823: 714

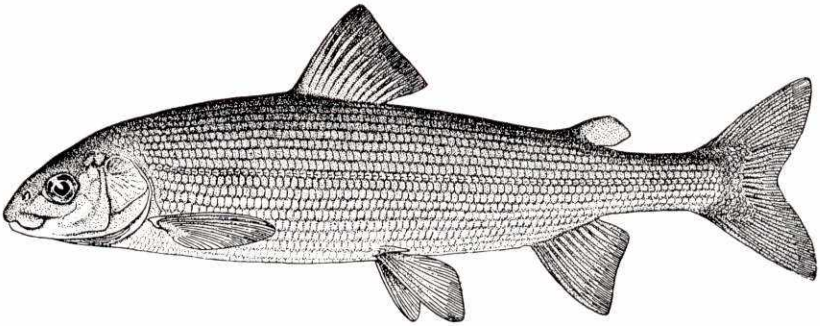
Salmo (Coregonus) quadrilateralis (Richardson)	— Richardson 1836: 204
Coregonus quadrilateralis Richardson	— Cox 1896b: 67
Prosopium preblei	— Harper and Nichols 1919: 266
Prosopium quadrilaterale Richardson	— Hubbs 1926: 13
Prosopium quadrilaterale (Richardson)	— Jordan, Evermann, and Clark 1930: 65
Prosopium cylindraceum (Pallas)	— Dymond 1947: 8

Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *cylindraceum* — like a cylinder.

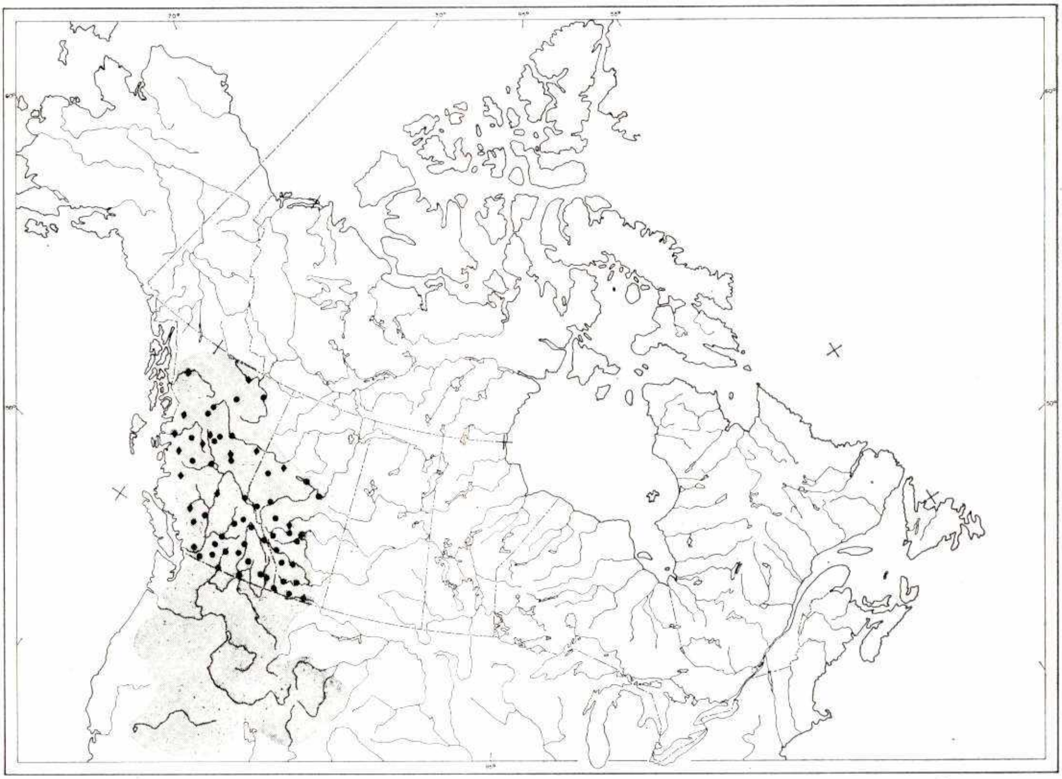
Common names Round whitefish, pilot fish, frost fish, round fish, round-fish, Menominee whitefish. French common name: *ménomini rond.*

MOUNTAIN WHITEFISH

Prosopium williamsoni (Girard)



Description Body slender, elongate, average length 8–12 inches (203–305 mm), body nearly cylindrical in cross section but variable, more compressed laterally than round whitefish, most young appear to be moderately compressed laterally. Head short, its length about 20% of total length; eye moderate, its diameter less than snout length; snout more or less pointed, compressed laterally, pinched, rounded in lateral view, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly almost to anterior margin of eye of adults; teeth small, restricted to a small patch on tongue and on gill rakers of adults, although small teeth may be present on the premaxillae of young, but absent from jaws, vomer, palatines, and premaxillae of adults. Gill rakers short, total range 19–26, usually 8–11 on lower limb of gill arch, 11–15 on upper limb, gill rakers with teeth. Branchiostegal rays 7 + 7 to 10 + 10. Fins: small adipose dorsal present, rayed dorsal with 11–15 rays; caudal distinctly forked; anal rays 10–13; pelvic abdominal, 10–12 rays, a distinct pelvic axillary process present; pectoral rays 14–18, no pectoral axillary process. Scales cycloid, large, usually outlined with black or dark pigment; lateral line complete, 74–90



scales. Pyloric caeca variable, 50–146. Vertebrae 53–61. (*See also* Holt 1970 and Norden 1970.)

Nuptial tubercles developed on scales of sides of spawning males, very transitory according to Hagen (1970) but Vladykov (1970) presented figure showing development of tubercles on first 3 or 4 rows of scales above and below lateral line but not on head.

Colour Overall colouration silvery, but light or dark brown or olive on back, becoming silvery on sides and white below. Scales, especially on back, may have pigmented borders. Dorsal fin often dusky, pelvic and pectoral fins of adults with amber tint.

Young are silvery with two or more rows of black spots on sides; the lower row, arranged along the lateral line, consisting of eight to ten large, dark spots or parr marks, usually distinctly larger and more like typical salmonid parr marks than those on young round whitefish.

Systematic notes *Prosopium oregonium* was once considered to be a distinct species but Holt (1960) made a comparative morphometric and meristic study of the species and compared it with other members of the genus *Prosopium*. She concluded that *P. oregonium* was not distinct from *P. williamsoni* and presented considerable data on the species from various watersheds in support of her conclusions.

Distribution The mountain whitefish occurs only in the lakes and streams of western North America, from the Lahontan basin in Nevada, north through the northwestern states including Wyoming, Montana, and Idaho, to the Yukon–British Columbia border.

In Canada, it occurs in rivers and lakes of the foothill country of western Alberta from the Milk River north through headwaters of the South and North Saskatchewan rivers to the Peace River. It is widespread in British Columbia from the Fraser and Columbia River systems, throughout the Pacific coastal drainages of the Bella Coola, Skeena, Nass, and Stikine systems and inland in the Peace and Liard systems, attaining its northern limit in the latter.

Biology Spawning occurs in late fall or early winter over gravel or gravel and rubble, but the exact time of spawning varies throughout the range. No nest is prepared. The findings of different investigators are not in accord on such questions as whether lake-dwelling populations spawn on gravel shallows in lakes, or seek gravel beds in tributary streams, or whether spawning is activated by a falling temperature. Obviously, much remains to be learned about the spawning behaviour of this species. Lake spawning in Wyoming was reported by Hagen (1970) who also provided a review of times and places of spawning reported in the literature. In some areas at least, such as in Montana, spawning occurred from October to early November, at depths of 5 inches to 4 feet, and took place at night (Brown 1952). Night spawning was also reported for Kootenay Lake, where McPhail and Lindsey (1970) noted the presence of two or more types or races that may have spawned at different times and places, from October to February.

The eggs are relatively large and, when water-hardened, averaged 3.7 mm in diameter (Brown 1952). The number of eggs retained by females generally increases with increase in size. In a study of Montana females, Brown found egg numbers to vary from 1426 for a female 10.2 inches (259 mm) total length, to 7271 for one 17 inches (432 mm) long. A single female, 19.5 inches (495 mm) long, and weighing 48 ounces, twice the weight of the 17-inch fish, carried 24,143 eggs. Hagen (1970) gave a figure of 7757 eggs per pound of female. Most studies, however, indicate averages in the order of about 5000 eggs.

Development of eggs was described in detail by Brown (1952). In Montana, eggs deposited in late October or early November hatched in early March. Newly hatched fry could be found in stream shallows for a few weeks but at lengths of 1.2–1.6 inches (30–40 mm) they moved offshore.

Ages can be determined by scale examination. McHugh (1942) observed no difference in growth rates of males and females. There is, however, considerable variation in growth rate throughout the range, as indicated by the following table, modified from Northcote (1957), which shows the variation in average lengths for mountain whitefish populations in British Columbia, Alberta, Utah, and California.

Age at end of year	TL (*inches*)	TL (*mm*)
1	2.6–5.3	66–135
2	4.2–8.8	107–224
3	6.4–11.7	163–297
4	7.7–12.9	196–328
5	8.7–13.0	221–330
6	11.2–14.1	284–358
7	12.8–15.4	325–391
8	13.8–16.4	351–417
9	14.8–17.4	376–442

Fish become sexually mature at age 3 or 4. The maximum age attained appears to be 17 or 18 years in Bow Lake, Alta., reported by McHugh (1942). The largest mountain whitefish specimen known to the present authors is one reported by McPhail and Lindsey (1970) as the world's record. It was angled in Lardeau River, B.C., by R. A. Rutherglen, weighed 4 pounds 7 ounces (2013 g) and was 22.5 inches (572 mm) long.

The mountain whitefish inhabits lakes and larger rivers, apparently preferring large streams to small. It may inhabit small, turbid pools as well as cold, deep lakes, but tends to frequent the upper 15–20 feet (4.6–6.1 m) and seems seldom to occur below 65 feet (20 m). In the Skeena River system it was considered most abundant in shallow, eutrophic-type lakes. In Alberta, the ability of mountain whitefish to adapt to changing conditions, in this case hydro-electric development, was demonstrated by Nelson (1965).

It is primarily a bottom feeder consuming a variety of organisms, especially aquatic insect larvae such as those of mayflies, stoneflies, caddisflies, and midges, small molluscs, and, on occasion, fishes. A prickly sculpin was found in the stomach of a mountain whitefish caught in Kootenay Lake. When bottom fauna is scarce, mountain whitefish will eat midwater plankton and surface insects, but under these conditions, the species is usually less abundant (Godfrey 1955). Chironomids dominated the diet in Alberta reservoirs (Nelson 1965). Like most fishes adapted to bottom feeding, it will eat the eggs of its own and other species (Foerster 1925; Simon 1946) and although eggs of sockeye and coho have been recorded in stomach contents, it is doubtful that such activities are seriously detrimental to these fish. Ricker (1941) demonstrated that they will eat young fishes, for one specimen from among 53 examined from Cultus Lake, B.C., had 10 small sockeye in its stomach.

Mountain whitefish appear to have few predators (other than the universal one — man) but Godfrey established that in the Skeena Lakes, lake trout, and possibly burbot, will eat them. Like other round whitefishes, it will also eat its own eggs (Simon 1946). In some regions it competes with rainbow trout and salmon (*Oncorhynchus* spp.) since it eats the same kinds of food as these species.

Bangham and Adams (1954) examined 253 specimens of Rocky Mountain whitefish from 19 locations in the Columbia, Fraser, Skeena, and Peace River drainages and found 213 infected. The list of species is extensive; consult publication for details.

Hoffman (1967) listed approximately 30 species of parasites, involving trematodes, cestodes, nematodes, acanthocephalans, and crustaceans, but *see* publication for details.

Relation to man The mountain whitefish has been fished for food in many parts of British Columbia for many years. McHugh (1940) noted that before its sale was banned prior to 1940, it was even peddled from door to door. In recent years, it has gained popularity as a game fish in British Columbia and Alberta. It is fished by fly or with a small hook baited with stonefly larvae, salmon eggs, corn, or maggots. Fishermen sometimes call this whitefish "grayling", an unfortunate and erroneous local name.

Would-be anglers might enjoy a publication by John Gaffney (1960) on the utilization of mountain whitefish in Montana. Gaffney provided information on methods of fishing, where to fish, baits, preparation of catch including home smoking, and recipes for cooking whitefish.

The mountain whitefish has not been shown to be a serious predator on salmon or trout in Canadian waters (McHugh 1940; Godfrey 1955) although it does occasionally eat eggs and young of other species and may be a minor competitor for food in some areas.

Nomenclature

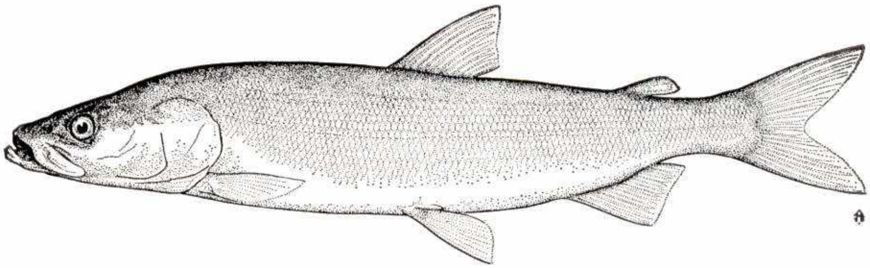
Coregonus williamsoni	— Girard 1856a: 136 (type locality Des Chutes R., Ore.)
Prosopium oregonium	— Dymond 1943: 201
Prosopium williamsoni (Girard)	— Dymond 1947: 8
	— Holt 1960: 192
	— Scott and Crossman 1969: 13

Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *williamsoni* — after Lieut R. S. Williamson of the United States Pacific Railroad Exploration.

Common names Mountain whitefish, Rocky Mountain whitefish, Williamson's whitefish, grayling. French common name: *ménomini des montagnes.*

INCONNU

Stenodus leucichthys (Güldenstadt)



Description Body elongate, total length usually 18–30 inches (457–762 mm), only moderately compressed laterally, greatest body depth near tip of depressed pectoral fin, greatest body depth usually less than head length, 20–23% of total length. Head long, broad, shallow, its length 24–28% of total length; eye moderate to small, its diameter 20–22% of head length; snout distinctly longer than eye; mouth large, terminal, lower jaw obviously projecting beyond upper, maxillary extending to below middle of eye or beyond; small, fine teeth developed on anterior part of lower jaw, tongue, premaxillaries, head of maxillaries, vomer, and palatines. Gill rakers, range in total count 19–24 (6–9 on lower arm of gill arch). Branchiostegal rays 9–12. Fins: small dorsal adipose present; dorsal 1, high, pointed, rays 12–19; caudal distinctly forked; anal rays 15–18; pelvic rays 11, pelvic axillary process well developed; pectorals long, rays 16 or 17. Scales cycloid, large, 90–110 in lateral line. Pyloric caeca 150–202. Vertebrae 64–69.

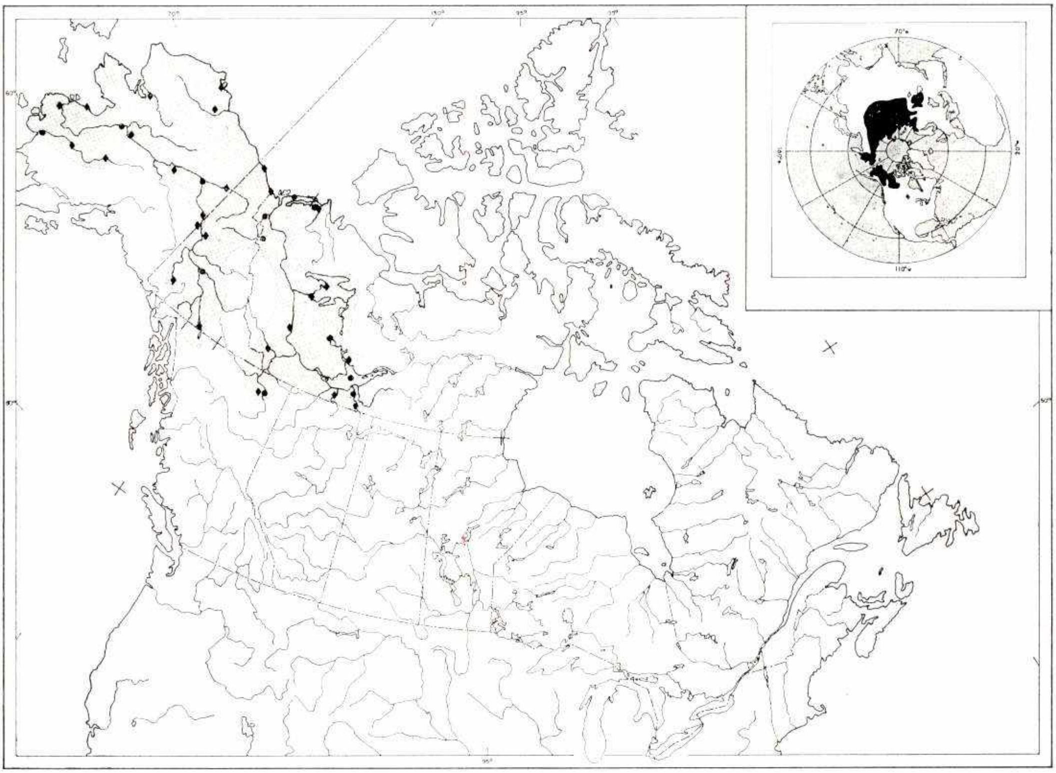
Nuptial tubercles or pearl organs not developed.

(*See also* Dymond 1943; McAllister 1962b; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; usually green to pale brown on the back, especially when young, silvery on sides and silvery white below. Dorsal and caudal fins tipped with dark pigment, remaining fins clear or immaculate.

Systematic notes The species was described by Güldenstadt (1772) as *Salmo leucichthys* based on specimens from Caspian Sea drainages. The Siberian form was described by Pallas (1776) as *Salmo nelma* and the North American form by Richardson (1823) as *Salmo Mackenzii*. The North American form was generally known as *Stenodus mackenzii* until Dymond (1943) adopted Berg's (1932) view that the North American and Asian forms were conspecific and suggested that the North American form be designated *Stenodus l. mackenzii*. Walters (1955) and, later, Shaposhnikova (1967) demonstrated that the North American and Siberian forms were not subspecifically distinct and both should be referred to the subspecies *S. l. nelma*. The typical subspecies *S. l. leucichthys* is restricted to the Caspian Sea drainage.

Distribution The inconnu occurs in northwestern North America and west in the arctic drainages of northern Asia to the White Sea. An isolated population occurs in the northern Caspian Sea and its inflowing rivers. In North America, it ranges from the Kuskokwim River in the Bering Sea drainage of Alaska, north in coastal rivers to the Anderson River near Cape Bathurst, N.W.T.; in many parts of the Yukon River system to its headwaters (Teslin Lake), in southern Yukon Territory and northern British Columbia. It ranges through the Mackenzie River to Great Slave Lake and up the Slave River to



Fort Smith, and to Fort Nelson, B.C., on the Liard River.

Biology The biology of the inconnu has received more attention in Siberia than in Canada, and few recent studies of Canadian populations have been published.

Spawning probably occurs in late summer or early autumn in rivers, but there are no direct observations concerning behaviour during spawning or the kinds of spawning grounds used. It is suspected that individual fish spawn only once every 2, 3, or 4 years. In the Yenisei River, Siberia, Nikol'skii (1954) noted that egg number varied from 125,000 to 325,000 eggs. Although direct observations of spawning of Great Slave Lake populations have not been made, there are conspicuous downstream migrations following the time that spawning should take place, hence, it is considered that spawning probably occurs in those rivers having marked downstream runs in the fall of the year. Great Slave Lake rivers exhibiting such marked downstream runs are Big Buffalo and Taltson rivers, which have largest runs, and Slave, Little Buffalo, and Hay rivers with smaller runs. The upstream, presumably prespawning migration, is prolonged and apparently continues all summer.

Young inconnu are thought to remain in Big Buffalo River for at least 2 years before descending to Great Slave Lake. At about age 4 there was a marked acceleration of growth which Fuller (1955) thought might have been associated with a change in diet from benthos to fish. The rate of growth was fairly rapid, more rapid than that of the lake whitefish or lake trout, and Fuller reasoned this was so because the inconnu is an arctic fish at the southern part of its range, whereas the others are subarctic or temperate species at their northern limit.

The growth rate of Great Slave Lake fish is given in the following table (from Fuller):

Age (years)	SL (inches)	SL (mm)	Weight (lb)
1+	5.8	146	0.12
2+	9.7	247	0.44
3+	12.3	312	0.87
4+	15.9	403	1.62
5+	18.6	473	3.00
6+	20.8	529	4.36
7+	22.5	572	5.62
8+	24.0	610	7.13
9+	25.9	657	8.31
10+	27.1	688	9.75
11+	28.6	727	11.05

In Great Slave Lake inconnu mature in 7–10 years, but few live longer than 11 years, although Siberian fish live at least 21 years according to Nikol'skii (1954).

The inconnu grows to a larger size than any other whitefish species. One weighing "just over 63 pounds" and measuring 59.25 inches (1.5 m) long, was caught by K. H. Lang at the mouth of the Mackenzie River, July 12, 1936 (Dymond 1943). Lang reported, also, that he had seen several that weighed between 45 and 55 pounds, that 20–30-pound fish were common, but that the average weighed 6–12 pounds. In the Great Slave Lake drainage, the largest known fish weighed 55 pounds and was caught in Big Buffalo River about 1943; one weighing 54.7 pounds, and measuring 50 inches (1.27 m) fork length, was caught in Great Slave Lake in 1960 (Keleher 1961).

The inconnu is an anadromous species in coastal areas, ascending freshwater streams from the sea to spawn, but in inland lakes, such as Great Slave, it remains in fresh water throughout its life, migrating up tributary streams in summer, returning to the lake in late fall. These fall downstream runs are the spectacular ones and it is during this downstream run that inconnu are most readily caught.

The food of adults in Great Slave Lake consists almost entirely of small fishes, mainly young whitefishes but also northern pike, ninespine sticklebacks, young goldeye, minnows, arctic lamprey, and occasional small inconnu. (Dymond 1943; Rawson 1951; Fuller 1955.)

In the Yukon River, Alaska, inconnu also ate young chinook salmon, up to 16 per stomach in a study conducted by Alt (1965). Young inconnu eat aquatic insect larvae and planktonic crustaceans. Fuller concluded that inconnu changed from an invertebrate diet in rivers to a fish diet on entering Great Slave Lake and the adult phase of their lives.

Adult inconnu have few enemies except man, but Larkin (1945) reported that mature inconnu caught in the lower part of Big Buffalo River (Great Slave Lake) were gorged with young inconnu. Inconnu were also found in the stomachs of northern pike and burbot in Great Slave Lake (Rawson 1951).

The parasites harboured by the inconnu of Great Slave Lake were noted by Fuller (1955) who made particular mention of encysted *Triaenophorus crassus* in the muscle tissue. (*See Coregonus clupeaformis* for detailed account of *T. crassus.*) Other parasites reported by Fuller were *Proteocephalus* sp. and *Eubothrium* sp. in the intestine and *Salmincola* sp. on the gills.

Hoffman (1967) listed 8 trematodes, 5 cestodes, 2 nematodes, 1 leech, and 5 crustaceans that have been reported parasitic on inconnu in Soviet waters.

Relation to man Much has been written about the use of the inconnu for human and dog food by northern travellers. Its flesh is greatly appreciated by some but considered less than appetizing by others. Dymond (1943) quoted K. H. Lang, a local resident who fished the Mackenzie River in the vicinity of Aklavik, as follows: "It is a beautiful fish and in very much favour as human food, and also as dog food, although the smaller connie are a little dry and lean; but the bigger they are the fatter they get, and a piece of the tail of a big connie is generally considered the best feed of fish obtainable in the country." Richardson (1823) was less glowing in his praise and considered the inconnu "disagreeable when used as daily food." The palatability probably varies with the season and place of capture, as well as size of fish. For local use they are usually caught by gillnet, employed during the downstream runs in late autumn. The fish were usually split, and hung in the open air to dry, or were smoked. For additional information on local fisheries *see* Dymond (1943) and Melville (1914).

Commercially, Great Slave Lake inconnu are caught in gillnets. They are sold fresh or frozen, usually headless and dressed, at a wholesale price that fluctuates around 50 cents per pound. They are sold mainly on the United States market to be used in the smoked fish trade. Occasionally, they are offered for sale in major Canadian cities but a retail trade for fresh inconnu has not been developed. The oily flesh is probably better suited to smoking than to the fresh fish trade.

During the period 1953–1963, the commercial catch of inconnu from Great Slave Lake ranged from a low of 165,000 pounds in 1955 to a high of 344,000 pounds in 1963, but the catch appears to have fluctuated according to demand and not because of availability (Sinclair et al. 1967).

Some attention has been directed to inconnu as a sport or game fish, especially in Alaska, but Canadian stocks are seldom used by sportsmen. In a recent survey of fishing in Great Slave Lake, Keleher (1966) reported that, although stocks were adequate to support a commercial fishery, proper angling methods had not been discovered locally and, hence, a potentially valuable sport fishery was not being utilized.

Nomenclature

Salmo leucichthys	— Güldenstadt 1772: (type locality Caspian Sea drainages)
Salmo Mackenzii	— Richardson 1823: 707
Stenodus mackenzii (Richardson)	— Jordan and Evermann 1896–1900: 474
Stenodus leucichthys mackenzii (Richardson)	— Dymond 1943: 220
	— Carl and Clemens 1948: 39
Stenodus leucichthys nelma (Pallas)	— Carl, Clemens, and Lindsey 1967: 48
Stenodus leucichthys (Güldenstadt)	— Bailey et al. 1970: 17

Etymology *Stenodus* — narrow tooth; *leucichthys* — white fish.

Common names Inconnu, sheefish, connie, conny. French common name: *inconnu.*

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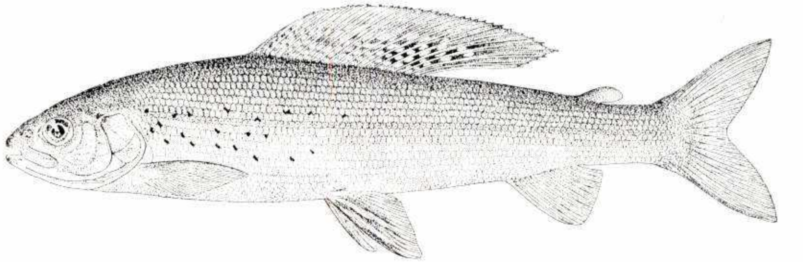
SUBFAMILY THYMALLINAE   Graylings, without orbitosphenoid, hypethmoid, suprapreopercle, or basibranchial plate; maxilla and premaxilla with teeth; with dermosphenotic and epipleurals; parietals meet at midline; scales, embedded margins indented; 17 or more dorsal fin rays; eggs small, a postlarval stage, young with parr marks.

ARCTIC GRAYLING

Thymallus arcticus (Pallas)



Description   Body elongate, laterally compressed, troutlike, cross section a long oval, average length 12–15 inches (305–381 mm), greatest body depth near dorsal fin origin 18.0–20.2% of total length; caudal peduncle long and slender. Head short, 16–17% of total length, shallow, narrow; eye rather large, diameter 22.5–25.7% of head length, about equal to snout length; snout short, 21.6–25.2% of head length; mouth moderate, premaxillaries nonprotractile; lower jaw sometimes longer than upper; maxillary moderate, extending only to middle of pupil, rather wide; teeth rather small, on both jaws (premaxillary, maxillary, dentary), tongue (sometimes absent in adults), head of vomer (few), palatines, no basibranchial (= hyoid) teeth (Atton, personal communication) reported tooth sockets on basihyal; a few small pharyngeal teeth. Gill rakers of moderate size, usually 16–23, usually 5–7 on upper limb and 11–15 on lower limb. Branchiostegal rays 7–9. Fins: dorsal adipose present; dorsal 1, the large size of this fin, especially in males is its most striking feature, base long, usually equal to or longer than head, fin very high, posterior rays greatly lengthened, vividly coloured, 17–25 total rays, depressed fin of mature males reaching to or beyond adipose fin, shorter in females, fin of male highest at back, that of female highest at front; caudal broad, deeply forked, tips pointed, lower lobe sometimes longer; anal rather small, edge square, 11–15 total rays; pelvics abdominal, under centre of dorsal fin, axillary process small, fin long, in mature males reaching almost to anus, shorter in females, broad, edge square, vividly coloured, 10 or 11 rays; pectorals low, long, rather pointed, 14–16 rays. Scales cycloid, moderately large (*see* Miller 1946b, for photos); lateral line complete, straight, 77–98 pored lateral line scales according to McPhail and Lindsey (1970) but Atton (personal communication) recorded 81–103 in material from Northwest Territories. Pyloric caeca 14–21. Vertebrae 58–62. Norden (1961a) gave extensive details of the osteology of this species and compared the grayling with other salmonoid fishes. Ward

(1951) gave counts and measurements for grayling in the Athabasca River in Alberta.

No nuptial tubercles and none of the body changes so characteristic of salmonids at spawning time, but colours darken and the males become more brilliant than the females.

Colour A strikingly coloured fish, the dorsal surface is dark purple, or blue-black to blue-grey, the sides are grey to dark blue with a pinkish iridescence, the ventral surface grey to white. The sides are marked with a varying number of V-shaped or diamond-shaped spots, mostly ahead of the pelvic fins (more on young), and a dark stripe between the paired fins. The head is olive-green with a mauve iridescence, black on the base of the branchiostegal rays and the eye is dark green and gold. The dorsal fin is basically black with a narrow, mauve edge, often with a wider blue band below, and vertical rows of orange-red or mauve to emerald green spots, largest at the top and on the long, flexible, posterior lobe. The adipose, caudal, anal, and pectoral fins are dusky to bronze. The pelvic fins are black and crossed on an angle (not vertical between the rays) by wavy, mauve or orange lines. Females are similarly but less brightly marked.

The young are deeper than most salmonids, greenish above with a large dorsal, 10–20 dark parr marks straddling the lateral line, and small, black spots or dark broken lines above them.

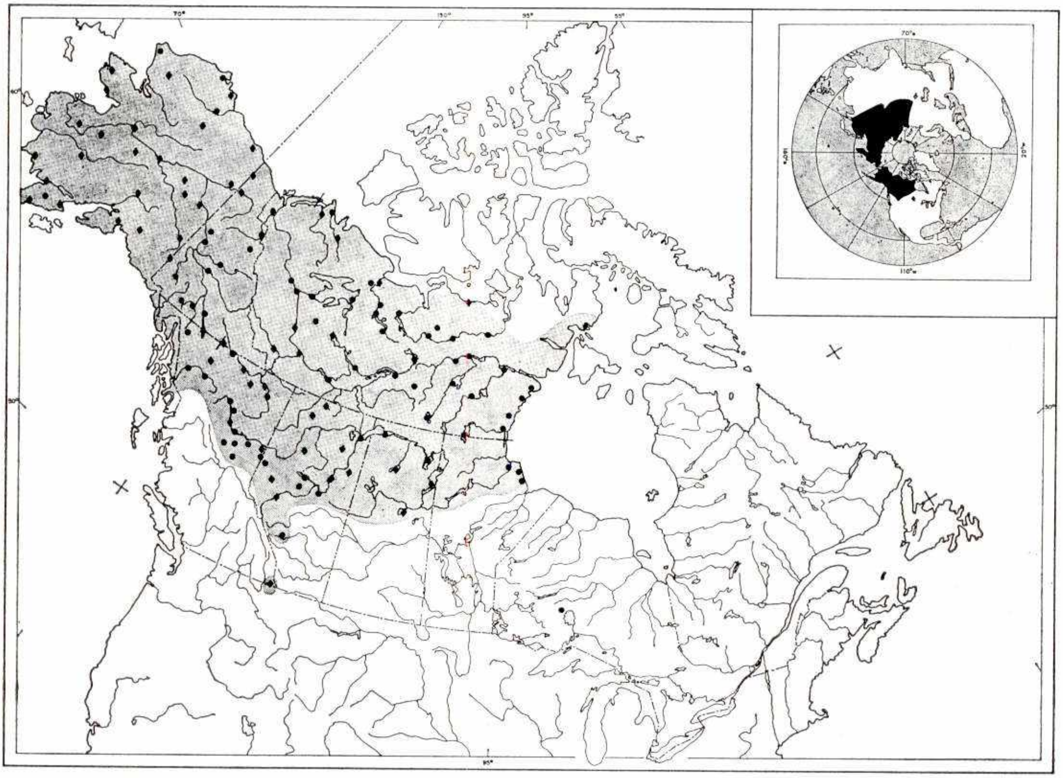
Systematic notes The graylings were, until recently, placed in a separate family, Thymallidae, and some authors still do so. There are four species, *T. brevirostris* (Mongolia), *T. thymallus* (Britain to central Europe), *T. nigrescens* (Lake Kosogol, Mongolia) and *T. arcticus* (with several subspecies — western Siberia and North America). At one time in North America there were three or four isolated stocks which were referred to as separate species, *T. signifer* Richardson (Alaska and northern Canada), *T. montanus* Milner (Upper Missouri River), *T. tricolor* Cope (Upper Great Lakes tributaries in Michigan, now extinct), and two specimens named *T. ontariensis* Cuvier and Valenciennes, thought to have come from the Great Lakes but generally presumed to have erroneous locality data. Walters (1955) considered *T. signifer* synonymous with *T. arcticus* and the others as subspecies of it. The validity of the subspecies distinctions in North America has not been adequately demonstrated.

Confusion may exist as the mountain whitefish is called grayling in certain northwestern areas.

Distribution The Arctic grayling has a holarctic distribution and occurs in northern freshwater drainages (and, rarely, in salt water in Asia) from Hudson Bay west including all of Alaska, St. Lawrence Island, Bering Sea, to the Kara and Ob rivers of northern Eurasia. It extends south in Asia to northern Mongolia and the Upper Yalu River. Grayling occur in the headwaters of the Missouri River above Great Falls, Mont., and populations there have been maintained by fish culture and introduction from Canada. A population that once existed in rivers flowing into lakes Michigan, Huron, and Superior in northern Michigan, disappeared about 1936 even after introductions from Montana into the original habitat and elsewhere in Michigan. They have been introduced into the mountainous areas of such states as Vermont, Utah, and Colorado.

Arctic grayling occur in Canada from Vansittart Island off Melville Peninsula south along the west coast of Hudson Bay to the Owl River, Man., west throughout the Northwest and Yukon territories (excluding other arctic islands), south in Saskatchewan to Reindeer Lake but absent from much of the Churchill River, south to central Alberta and in northern British Columbia from the Peace and Stikine rivers north. They also occur in extreme southeastern British Columbia in the Flathead River, and southwestern Alberta in the Belly River, having spread there from Montana. *See* Fowler (1948), Rawson (1950), Carl et al. (1967), Paetz and Nelson (1970), and McPhail and Lindsey (1970) for more detail.

In 1959 thousands of yearling to 4-year-old grayling were stocked in 16 rivers



and lakes in Thunder Bay, Kenora, Geraldton, and Nipissing districts of Ontario. The museum has four specimens 13.7–15.7 inches (350–400 mm) from Blue Lake, Thunder Bay District, taken in 1961. It is presently considered, however, that there are no grayling in Ontario. Over a 10-year period, 10 million grayling fry were stocked in Lac la Ronge, Sask. They are reported to be established in one inflowing river. The species has been established in several small Saskatchewan lakes.

Biology Grayling spawn during that period in which the ice is first breaking up in the smaller streams. This varies over their subarctic to arctic habitat from April to June, and possibly later in some years. Spawning has been described by Rawson (1950) and Bishop (1971) for Reindeer River, Sask., and for Great Slave Lake. As the ice is breaking up in the small streams, adults migrate from ice-covered lakes and from larger rivers to small gravel- or rock-bottomed tributaries. Where there are no suitable small streams spawning takes place in gravelly to rocky parts of the main rivers. In Alaska spawning sometimes occurs in mud-bottomed vegetated pools below rapids. The run usually overlaps, or follows immediately after, that of northern pike, when water temperatures are 44.6°–50.0° F (7°–10° C). The males are territorial on the spawning grounds, chase intruding small males. If the male is another spawner there is a characteristic lateral threat display involving raised dorsal fin, extended pelvic fins, gaping mouth, lowered branchiostegals to display the black patch, and rapid vibration while swimming toward the surface. There is no spawning at night and it is most active during warmer water temperatures of midday. No actual nest or redd is prepared. During spawning the male curves the extended dorsal fin over the female almost like a clasping organ, the female gapes, there is vigorous vibration, the male gapes, sex products are discharged and somewhat covered by the material stirred up during vibration. The female may spawn once only, or several times in different areas. After spawning, adults return to the lakes or rivers.

Egg number per female in Great Slave Lake, by volumetric estimate, ranged from 6120–15,905 for fish 10–17 inches (254–432 mm) fork length and 24.5–45.0 ounces weight. Average number is probably 4000–7000. Egg size in the ovary is about 2.5 mm. Size after different periods of water hardening has been given as 2.7 mm (Bishop 1971) and as 6/inch = 4.3 mm (Rawson 1950). The eggs are amber, demersal, and apparently adhesive for only a short time. No parental care is given eggs or young. Hatching takes place rather quickly for the area and temperature, 13–18 days at 44.6°–51.8° F (7°–11° C). Early development of grayling in Montana was discussed in detail by Watling and Brown (1955). The young are only about 8 mm long when hatched and spend another 8 days absorbing the yolk but apparently take food 3 days after hatching. Growth is rapid at first. Young-of-the-year in Neultin Lake, N.W.T., were 2½ inches (64 mm) long by late August (Harper 1948) but were without scales. Growth in later years is variable with latitude and temperature, slower farther north. Age can be determined by scales and size at previous annuli back calculated (Miller 1946b). The table below gives age–length relation for various habitats. *See* Reed (1964) for summary of growth in various types of Alaskan habitats.

Some males and females reach sexual maturity at 4 years of age but the largest percentage (93.5%) of spawners are 6–9 years of age in Great Slave Lake. Most spawning fish over 9 years of age are females. Spawners in Reindeer River are mostly 5 and 6 years old, 16–20 inches (406–508 mm) long and weigh 2.1–3.8 pounds. Adults spawn several times but possibly not all of them every year. Maximum age would appear to be 11 or 12 years. Maximum known size in Canada and present angler record is that of a grayling 29⅞ inches (757 mm) long (fork length?), 15⅛ inches (385 mm) in girth, and 5 pounds, 15 ounces in weight. It was caught in the Katseyedie River, N.W.T., in 1967. A specimen 5 pounds, 7 ounces and 21 inches (530 mm) long caught in Great Bear Lake was the previous record.

The general habitat of the grayling is the clear waters of large, cold rivers, rocky creeks, and lakes. They live in bog-fed areas in some parts of Alaska. In some areas in summer, they apparently inhabit lakes, and in others, streams. They avoid turbid parts of the Mackenzie River but enter milky, glacial streams. In other areas they move into large rivers during freeze-up. Reed (1964), as well as giving their life history, gave details of physical and chemical characteristics of their habitats in Alaska. Grayling are usually associated with Pacific salmons; lake, rainbow, and cutthroat trouts; Dolly Varden; inconnu, and other whitefishes; and northern pike. In gillnet sets in Great Slave Lake, grayling were taken only to 10 foot (3.05 m) depth.

Food of the young is mainly zooplankton with a gradual shift to immature insects, mainly mayflies, caddisflies, and midges, with increase in size. The adults consume a very broad assortment of invertebrates but mainly aquatic and terrestrial insects, including those mentioned, bees, wasps, grasshoppers, ants and a variety of beetles. Other items eaten

		Age								
	FL	1	2	3	4	5	6	7	8	9
L. Athabasca, Sask.	*inches*	4.4	7.5	10.0	12.0	13.7	14.8	–	–	–
(Miller 1946b)	*mm*	112	191	254	304	349	375	–	–	–
Prairie Creek, Alta.	*inches*	4.3	6.7	8.9	10.6	11.8	12.4	12.8	–	–
(Ward 1951)	*mm*	109	171	226	269	300	316	326	–	–
Great Bear L., N.W.T.	*inches*	3.7	6.1	9.1	11.2	12.8	13.9	14.9	15.7	16.2
(Miller 1946b)	*mm*	93	155	231	285	325	353	378	399	410
Little Salcha R., Alaska	*inches*	3.6	5.3	7.5	9.1	10.8	11.4	12.0	–	–
(Wojcik 1956)	*mm*	90	135	189	232	274	289	304	–	–

are small quantities of fishes (grayling and cisco) fish eggs, lemmings, and plankton crustaceans (Miller 1946b). Food was analyzed in great detail for several areas in northern Saskatchewan by Rawson (1950).

Very little is known of the predators of the grayling. Other fishes and predatory birds such as eagles, osprey, gulls, and mammals such as mink and otter, probably prey on the young and smaller adults. Grayling, as a result of the quantity of terrestrial insects taken at the surface, do not constitute serious competitors of other fishes. Their ease of capture, late maturity and slow growth, and need for clear, cold, unpolluted water endanger them in populous areas.

Parasites reported for this species from Great Bear Lake by Miller (1946b) were the cestodes *Triaenophorus crassus, T. nodulosus*, and *Cyathocephalus* sp.; unidentified nematodes; the acanthocephalan *Echinorhynchus coregoni*; and the copepod *Salmincola thymalli*. Bangham and Adams (1954) added the trematode *Crepidostomum* sp., and the nematode *Metabronema* from the Peace River in British Columbia. Hoffman (1967), who listed parasites of grayling from North America, Russia, and Iceland, added the trematodes *Tetraonchus alaskensis* and *T. rauschi*.

In 1969 Schmidt reported a new species of acanthocephalan, *Paracanthocephalus rauschi*, from this species on St. Lawrence Island, Bering Sea.

Relation to man This species has been taken by Eskimos and Indians in the past in moderately large numbers as food for their dogs and, less often, for themselves. This was usually done only when trout and whitefishes were scarce. Miller (1947) reported that one Franklin Indian on Great Bear Lake took as many as 22,000 in 1 year. These were taken in June in stream traps and dried. Otherwise the relationship is an aesthetic one. The beautiful fish is a joy to behold and one of the few species over much of the northern part of Canada that will provide fly fishing. The preponderance of surface insects in the food, their habit of testing almost everything on the surface of the water, their schooling habit and tendency to leap when hooked, make them an attractive sport fish. Anglers also catch them with natural bait and a variety of small spinning lures. In such places as the Bear River near Fort Franklin, Great Bear Lake, they can be readily caught in fair numbers averaging 12–16 inches (305–406 mm) and 1–2 pounds weight. Fly fishermen are willing to pay considerable fees to fly into northern Canadian areas to catch this beautiful fish, which occurs in abundance only there.

Nomenclature

Salmo arcticus	— Pallas 1776: 35 (type locality Ob River, Siberia)
Coregonus Signifer	— Richardson 1823: 711
Coregonus Thymalloides	— Richardson 1823: 714
Salmo (Thymallus) signifer (Richardson)	— Richardson 1836: 190
Salmo (Thymallus) thymalloides (Richardson)	— Richardson 1836: 194
Thymalus ontariensis	— Cuvier and Valenciennes 1848: 452
Thymallus tricolor	— Cope 1865: 80
Thymallus Pallasii	— Dall 1870: 579
Thymallus montanus	— Milner 1874: 741
Thymallus signifer	— Günther 1866: 202
Thymallus tricolor montanus Milner	— Whitehouse 1919: 52
Thymallus arcticus pallasi Valenciennes	— Berg 1936: 58
Thymallus signifer tricolor Cope	— Hubbs and Lagler 1947: 44
Thymallus arcticus	— Wynne-Edwards 1952: 16
Thymallus arcticus signifer (Richardson)	— Walters 1955: 290
Thymallus arcticus (Pallas)	— Scott 1958: 10

Etymology *Thymallus* — thyme-like, referring to its supposed odour like that of the herb thyme; *arcticus* — of the arctic.

Common names Arctic grayling, grayling, American grayling, bluefish, Back's grayling, sailfin arctic grayling, arctic trout, tittimeg, poisson bleu (of the voyageurs). French common name: *omble arctique*.

Suggested Reading – subfamily Thymallinae

FABRICIUS, E., and K.-J. GUSTAFSON. 1955. Observations on the spawning behaviour of the grayling, *Thymallus thymallus* (L.). Rep. Inst. Freshwater Res. Drottningholm 36: 75–103.

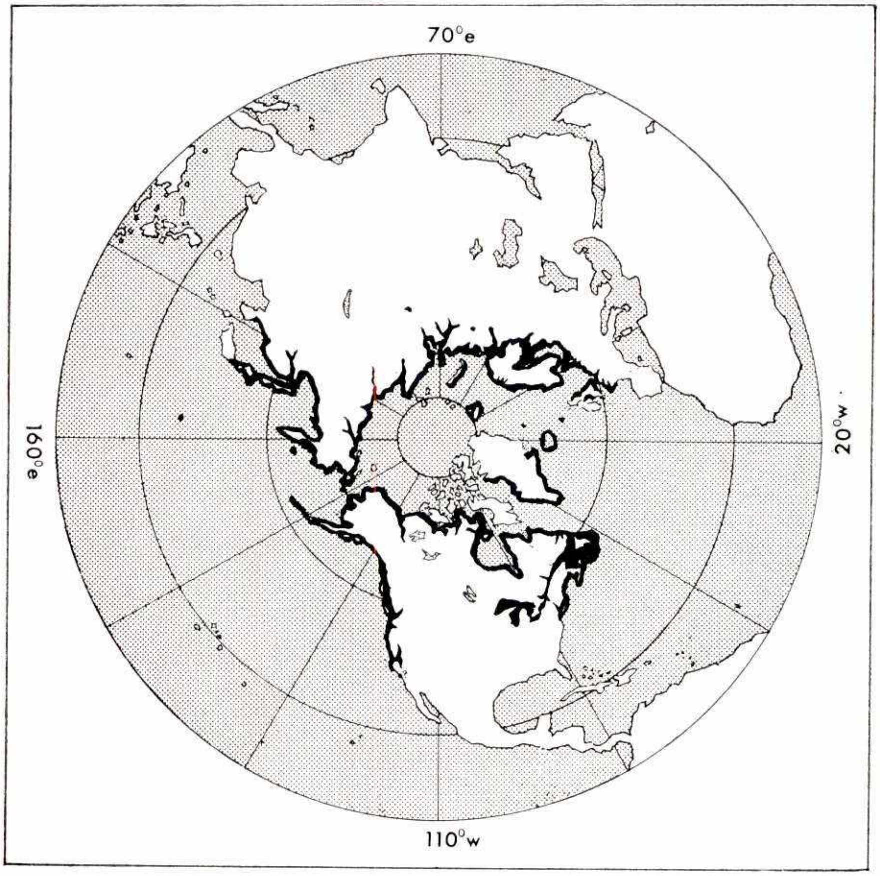
KRUSE, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish Wildl. Serv. Fish. Bull. 149, vol. 59: 307–351.

NORDEN, C. R. 1961. Comparative osteology of representative salmonid fishes, with particular reference to the grayling (*Thymallus arcticus*) and its phylogeny. J. Fish. Res. Bd. Canada 18: 679–791.

Smelt Family — Osmeridae

Small, slender, silvery fishes, with elongate, laterally compressed bodies and large mouths. Teeth well developed (*Osmerus*) or weakly developed (*Mallotus*), on mesopterygoid, glossohyal, vomer, palatines, premaxillary, maxillary, and dentary. Branchiostegals 6–10. Adipose fin present. Scales, thin, cycloid, confined to body; lateral line present; pelvic axillary scale absent. Pyloric caeca 11, or 1 minute, or absent. Vertebrae 50–77; only urostylar vertebra is upturned and is not included in total count.

The smelts are circumpolar fishes, restricted to the northern hemisphere. They may be marine, anadromous, or freshwater in habit in Atlantic, Arctic, or Pacific oceans and their drainages. The family includes 6 genera and 10 species, but only 4 genera and species occur in Canadian fresh waters.



World Distribution of the Smelts

Key to Species

1 Gill rakers on upper half of arch 4–6; pyloric caeca 8–12; scales in lateral line 70–86, lateral line complete; pronounced concentric marks on operculum .... EULACHON, *Thaleichthys pacificus* (p. 320)

Gill rakers on upper half of arch 8–14; pyloric caeca 0–6; scales in lateral line 65 and fewer, lateral line incomplete; no obvious concentric marks on operculum 2

2 Maxillary extending only to middle of pupil; tongue teeth minute and villiform; pyloric caeca 0–4; snout somewhat rounded; rarely over 6 inches (150 mm) .... POND SMELT, *Hypomesus olidus* (p. 308)

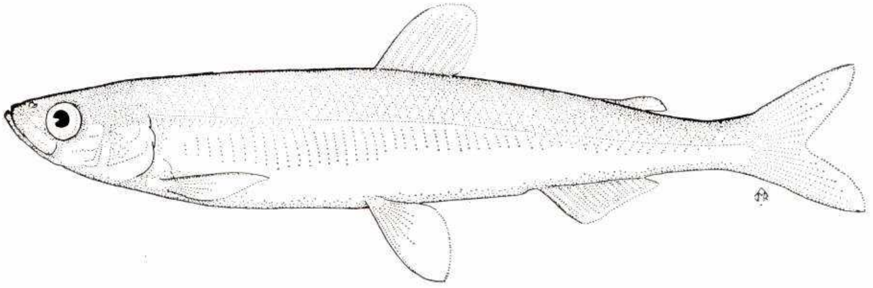
Maxillary extending beyond pupil, usually to posterior margin of eye; tongue teeth from small conical to large canine; pyloric caeca 4–11; snout more pointed; size larger 3

3 Gill rakers on lower half of arch 27–34, total gill rakers usually 37–47; anal rays usually 15–19; base of anal fin more than 3 times eye diameter; no enlarged teeth on tongue; rarely over 6 inches (150 mm) .... LONGFIN SMELT, *Spirinchus thaleichthys* (p. 318)

Gill rakers on lower half of arch 18–24, total gill rakers usually under 37; anal rays usually fewer than 16; base of anal fin about 2.5 times eye diameter; 1 or 2 prominent, curved, canine teeth on tip of tongue larger; size large, to 12.8 inches (324 mm) .... RAINBOW SMELT, *Osmerus mordax* (p. 310)

POND SMELT

Hypomesus olidus (Pallas)

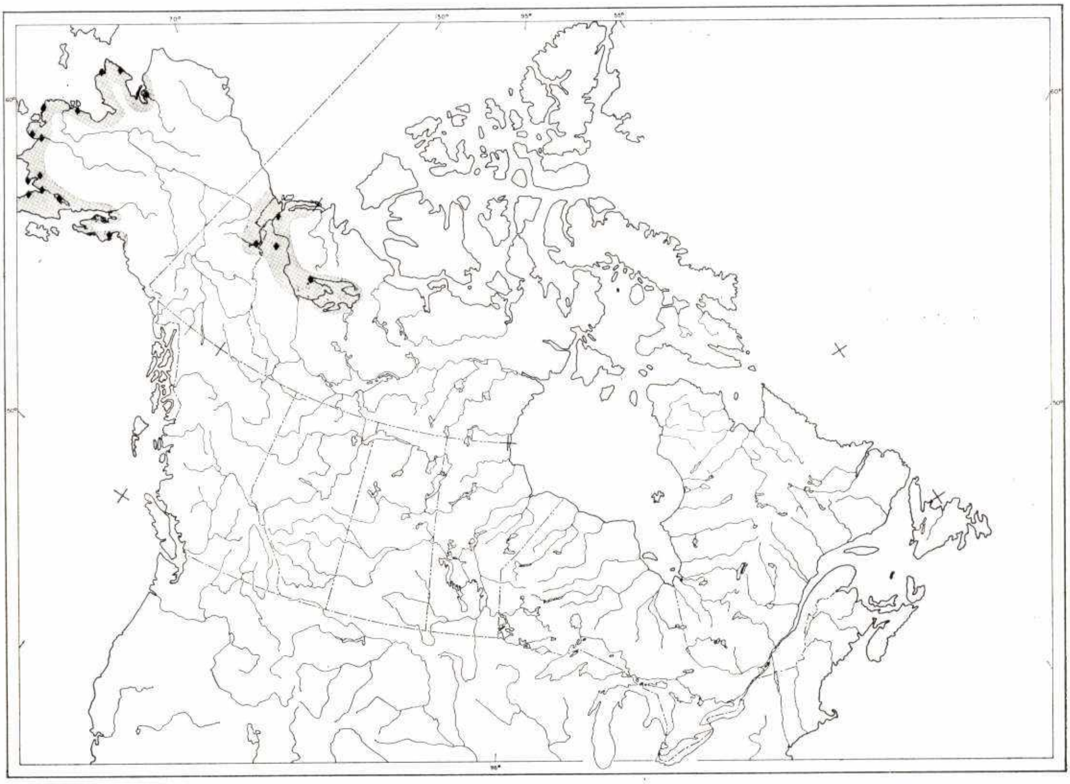


Description Body robust, subcylindrical in cross section, somewhat laterally compressed, greatest depth, at origin of dorsal fin, 15.8–23.8% of scaled or standard length of body; usually about 6 inches (150 mm) in total length. Head moderately long, 20–25% of standard length; eye moderately large, diameter 20.4–30.3% of head length; snout short, bluntly pointed; mouth small, oblique, maxillary extends to anterior edge or middle of pupil; small, pointed teeth on vomer, palatine, mesopterygoid, pharyngeal plates, basibranchial, dentary, maxillary, premaxillary, and tongue, but none enlarged. Gill rakers 26–34 (8–12 + 17–22), long and slender. Branchiostegal rays 6–8. Fins: single, soft-rayed dorsal fin at middle of body, 7–9 principal rays, upper edge slightly rounded; adipose present, low, its base 90–120% of eye diameter; caudal well forked and with 19 principal rays; caudal peduncle narrow and moderately long; anal with long base, edge slightly crescentric, 12–18 (usually 12–16) principal rays, longest ray 43.4–55.5% of head length; pelvics inserted below or ahead of origin of dorsal fin, with 8 rays, tip rounded, reach almost to anus in mature males, shorter in females; pectorals shorter than head, thoracic, low, with 10–12 or 13 rays. Scales large, cycloid, 51–62 in midlateral series; lateral line incomplete, extending less than head length along body, with 7–16 pored scales; pyloric caeca usually 2 in North America but 0–4 over whole range; physostomous, duct attaches behind anterior end of swim bladder. Vertebrae 51–62. There are well-developed tubercles on the scales, head and fins of spawning males, weak or usually absent on females. (McAllister 1963; McPhail and Lindsey 1970).

Colour Adults light brown to olive-green on the back, a metallic silver band along midlateral line (less pronounced in young), ventral surface silver-white; fins immaculate. Speckling along border of dorsal scales, a stripe on peduncle, snout and operculum. The peritoneum is light and slightly speckled (McPhail and Lindsay 1970; McAllister 1963).

Systematic notes Often divided into subspecies, the variability within populations of characters used to separate the subspecies shows that this is not warranted. This species has been confused with the two others in the genus, creating confusion in the literature. Populations in California recorded as *H. olidus* were described as a new species, *H. transpacificus*. Much of the Japanese literature prior to 1963 referring to this species probably pertained to *H. transpacificus nipponensis* (McAllister 1963).

Distribution The pond smelt occurs in eastern Asia, Japan, Korea, and northwestern North America. In Asia it extends from Wonsan, Korea, north to the Alazeya River, Siberia, Hokkaido, and Sakhalin. An isolated



population occurs in Lake Kugloe in the Kara Sea drainage of the USSR. In North America it is known from the Copper River north to the Kobuk River in Alaska: the Peel River, Yukon Territory, and the Mackenzie River from Inuvik to Great Bear Lake.

There is a gap of 1700 miles between the isolated population in Lake Kugloe and the nearest population in the Alazeya River, Siberia (McAllister 1963).

Biology Spawning occurs in streams in April or May in Asia, but Alaskan specimens were taken in spawning condition in early to late June. Spawning takes place in littoral areas over bottoms covered with organic debris. Jordan and Evermann (1896–1900) recorded the pond smelt as spawning in freshwater ponds. Some spawning may occur in streams in Alaska also. Eggs are adhesive and hatch in about 18 days at 50° F (10° C) in Black Lake, Alaska. By September the young pond smelt are about 1.2 inches (30 mm) long, at 1 year they are 2.4 inches (60 mm) long, and 3.2 inches (80 mm) long at 2 years of age. Very few live longer than the third year (McPhail and Lindsey 1970).

The largest specimens seen by McAllister (1963) were 4 inches (102 mm) long, but he cited Russian records up to 7.3 inches (185 mm).

In arctic North America this is a wholly freshwater species, unlike others in the genus, which are marine or euryhaline. McAllister (1963) suggested that it ventures into brackish water farther to the south. The pond smelt lives in lakes and streams.

Sato (1952) gave the food of young-of-the-year as rotifers and that of older and larger individuals as made up of rotifers, algae, insects, and crustaceans in varying amounts in different seasons. Sato was probably referring to *H. transpacificus*, but the diet of *H. olidus* in similar waters is probably the same.

McPhail and Lindsey (1970) claimed this species had no predators in Black Lake, Alaska, but that, as pelagic feeders, they may be significant competitors of juvenile sockeye salmon.

Relation to man Jordan and Evermann (1896–1900), probably quoting Turner (1886), said that the pond smelt was excessively abundant around St. Michael, Alaska, and that it was a sweet fish, excellent as food.

Turner (1886) had said that by May 20 in 1887 this species so filled a half-acre lake near St. Michael, Alaska, that the natives gathered thousands by simply throwing them out with a stick, and that a dipnet thrust would yield 2 or 3 gallons. He said when fried they were sweet and excellent eating and that the natives dried them on strings of grass. They are small but are probably used as food by local people wherever they are abundant, especially in Japan and Korea. They are not a commercial species in North America.

Nomenclature

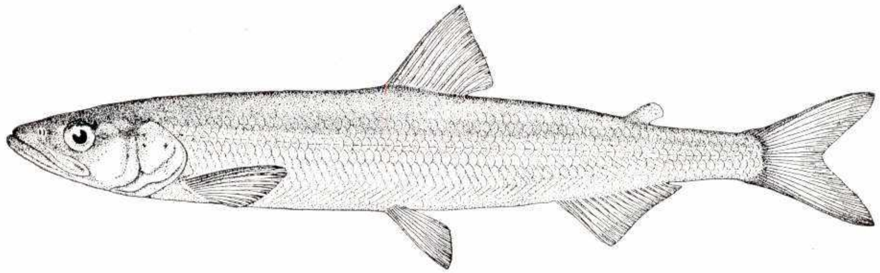
Salmo (Osmerus) olidus	— Pallas 1814: 39 (type locality Kamchatka)
Mesopus olidus	— Günther 1866: 169
Hypomesus olidus	— Jordan and Gilbert 1883a: 295

Etymology *Hypomesus* — below the middle, referring to the position of the pelvic fins; *olidus* — oily.

Common names Pond smelt, *malorotaya korioshka* in Russian, and *ishikari-wakasagi* in Japanese. French common name: *éperlan à petite bouche.*

RAINBOW SMELT

Osmerus mordax (Mitchill)



Description Body elongate, average length 7–8 inches (178–203 mm), laterally compressed, greatest depth anterior to dorsal fin origin, 12.6–13.8% of standard length. Head moderately long, its length 19.0–19.7% of standard length; eye moderately large, its diameter 17.5–24.0% of head length; snout elongate, pointed; mouth large, lower jaw protruding, maxillary extends to middle of eye or beyond, well toothed on vomer, palatine, pterygoid, basibranchial, dentary, maxillary, premaxillary, and tongue, teeth especially enlarged on tongue and front of vomer. Gill rakers 8–11 + 18–24, long, slender. Branchiostegal rays usually 7,7, but may be 5,7; 6,5; 6,6; 6,7; 7,6. Fins: dorsal 1, soft rayed, located at midbody, its origin over origin of pelvic fins, 8–11 rays; adipose present and well developed, its base 50.0–79.4% of eye diameter; caudal forked, with 19 rays; anal base long, rays 12–16, usually 13–15, longest ray 37.1–44.4% of head length; pelvics abdominal, fanlike, inserted below dorsal fin origin, 8 rays; pectorals shorter than head, low on sides, 11–14 rays. Scales cycloid, thin, deciduous, 62–72 in lateral series, perforate scales in lateral line 13–30, usually 14–28; lateral line incomplete. Peritoneum silvery with dark speckles; intestine short, pyloric caeca 4–8. Vertebrae 58–70, usually 60–66.

Nuptial tubercles small, like sandpaper to the touch, extensively developed over head, body and fins of males; seldom on females (*see* McKenzie 1964).

For additional data, *see* McAllister (1963), McPhail and Lindsey (1970).

Colour The rainbow smelt is a slender, silver fish, pale green on back, but with purple, blue, and pink iridescent reflections on the sides when freshly caught. Spawning males usually have small tubercles profusely distributed over the head and body and often do not show as colourful reflections as the females, although they are just as colourful when the nuptial tubercles are lost. The fins are generally clear. Populations of landlocked smelt in small inland lakes are often more darkly coloured than Great Lakes or sea-run smelt. Landlocked smelt may be black on head and back and even the fins may be suffused with black pigment. For a comparison of colour of anadromous and landlocked smelt *see Freshwater Fishes of Insular Newfoundland* (Scott and Crossman 1964, fig. 10, p. 76).

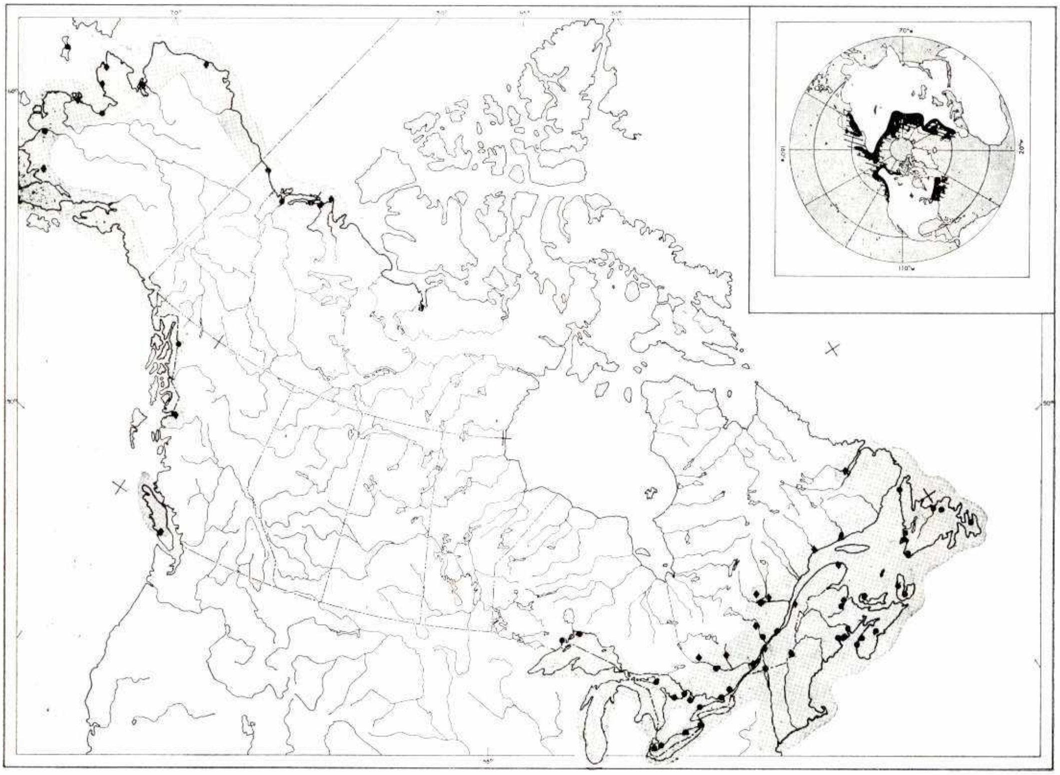
Systematic notes The following outline of the taxonomic history of North American smelts, admittedly brief and overly simplified, is presented with the hope that it will dispel some of the confusion that has arisen in the use of various scientific names for the commercially important eastern North American smelt.

For many years, the smelts of the genus *Osmerus* were considered by most North American ichthyologists to fall into three major taxonomic units — *O. eperlanus* of northwestern Europe; *O. dentex* of the North Pacific and Arctic Ocean waters of both northwestern North America and Asia; and *O. mordax* of northeastern North America. The two forms, *eperlanus* and *dentex*, were considered to be allopatric and, almost since the turn of the century, *dentex* was regarded by some systematists (Berg 1909, for example) as only subspecifically distinct from the type species, *Osmerus eperlanus*, although not all Europeans shared this view.

Gradually, the subspecific designation of *dentex* (i.e. *Osmerus eperlanus dentex*) gained acceptance among North American ichthyologists (Wynne-Edwards 1952; Walters 1955), but not, apparently, as a result of new information, although numerous systematic studies of *O. eperlanus* were written in many European languages. Most North Americans continued to regard the two North American populations as specifically distinct (i.e. *Osmerus dentex* and *O. mordax*) although the tenuous nature of the systematic distinction was soon voiced by Hubbs (1925b).

As early as 1893, Smitt (1893–1895) expressed the opinion that the North American Atlantic smelt was not distinct from the European, a view that was more widely accepted in Europe than in North America. Note, however, that Fortin (1863), in discussing St. Lawrence River fisheries, used *O. eperlanus* when speaking of local smelt.

Finally, a revision of the osmerid fishes was prepared by McAllister (1963), in which the position of the genus *Osmerus* was thoroughly reviewed. McAllister used data from many European studies, plus original data, and concluded that only one wide-ranging species existed: *O. eperlanus*, with two subspecies, *O. e. eperlanus* and *O. e. mordax*. The



subspecies *mordax* was regarded as wide ranging in North America and Eurasia, distinguishable from European *eperlanus* only by the number of pored scales (4–13 in *eperlanus*, 14–28 in *mordax*). McAllister noted, however, that "should sympatric populations of the two forms be found, which did not interbreed, it would be necessary to consider them full species." Such data were presented, albeit in a less than satisfactory form, by Kluikanov (1969) who also noted differences in skull characters and other features. Studies by the present authors indicate a wider range of variation in many characters than observed by Kluikanov and, hence, a weakening of his case. Kluikanov proposed the following nomenclature for smelts of the genus *Osmerus*: *Osmerus mordax mordax* — North American Atlantic smelt; *Osmerus mordax dentex* — North Pacific and Arctic ocean smelt; *Osmerus eperlanus* — European smelt. Thus, we seem to have gone around in a full circle, taxonomically speaking.

Perhaps McPhail and Lindsey (1970) were being realistic by referring to all smelts of the genus *Osmerus*, as the "*Osmerus eperlanus*" complex, and using the one common name "boreal smelt." But, giving all the populations a single name — putting them all in one bag, so to speak —does not make it any easier to talk about them or exchange information about them. Hence, although we are not in full agreement with Kluikanov's reasons, we propose to retain the name *O. mordax mordax* for the American Atlantic smelt, and *O. mordax dentex* for the Pacific and Arctic form, with the common names Atlantic rainbow smelt and Arctic rainbow smelt, respectively.

Distribution The taxonomic position of the species making up the genus *Osmerus* is uncertain at the moment for the reasons noted in the *Systematic notes*, and this nomenclatural uncertainty complicates distributional statements. Therefore, the following information on distribution applies to the so-called Atlantic rainbow smelt and Arctic rainbow smelt that inhabit North American waters.

The original range of the Atlantic rainbow smelt in eastern North America appears to have been restricted to the Atlantic coastal drainage from about New Jersey to Labrador. Reported occurrences south to Virginia are considered doubtful (Bigelow and Schroeder 1963). In addition to the anadromous populations, indigenous landlocked smelt occur widely in inland waters in many parts of eastern North America, such as New Hampshire, Maine, New Brunswick, Nova Scotia, insular Newfoundland (Bigelow and Schroeder's 1963 statement, p. 569, notwithstanding; *see* also Scott and Crossman 1964, p. 76), Labrador, Quebec, and even eastern Ontario (Dymond 1937). The northern limit of range along the North American Atlantic coast is the Hamilton Inlet–Lake Melville estuary, specifically Pike Run Cove, Lake Melville, at 54° 06′ N, 58° 20′ W (Backus 1957). Smelt are landlocked in many Quebec lakes in the St. Lawrence River drainage system, such as St. John, Edward, Memphramagog, Lac des Isles, and Champlain, to name only a few (*see* Delisle and Veilleux 1969, for additional information).

The range of the smelt in the inland waters of North America was extended greatly as a result of introductions into rivers and streams of the Great Lakes watershed. Its establishment in the Great Lakes themselves is generally concluded to have resulted from plantings made in Michigan waters flowing into Lake Michigan. These plantings commenced in 1906 but the planting in Crystal Lake, Mich., in 1912, is considered the one responsible for the eventual establishment of the species in Lake Michigan (Van Oosten 1937b), from whence it spread to all the remaining Great Lakes, except Lake Ontario. It was first reported from Lake Ontario, off Bowmanville, Ont., in 1931 (Mason 1933), 4 years before it was known to occur in Lake Erie; hence, it is unlikely that smelt reached Lake Ontario via Lake Erie, but it is equally unlikely that they occurred there naturally, as suggested by Hubbs and Lagler (1958). It is more plausible that smelt were introduced from waters in New York State via the Cayuga Lake–Cross Lake–Seneca River–Oswego River route.

The spread of smelt through Great Lakes waters has been considered in detail by many authors, notably Creaser (1925), Van Oosten (1937b), and Dymond (1944a). The subsequent spread into inland lakes of Ontario, by unauthorized introductions, has continued to the present day but the impact on native fishes is not known. Smelt are now known to occur in many lakes of the Parry Sound–Muskoka region where sizable spawning runs occur in some lakes, and even in Lake Simcoe where the species was first caught in 1962 (Scott 1963). We were unable to verify the suggestion by MacCrimmon and Skobe (1970) that smelt occur in Cameron and Sturgeon lakes of the Trent Canal System. It now occurs also in Eva Lake, Rainy Lake basin.

The Arctic rainbow smelt, called *Osmerus dentex* in much of the early literature, occurs from Vancouver Island, north to Yakutat on the Pacific Coast. On the Bering Sea side of the Aleutian Islands, it occurs from Bristol Bay, around the Alaskan coast to the Arctic Ocean, thence east along the Canadian coast to Cape Bathurst. This eastern limit is apparently based on a single specimen reported in 1913, which has subsequently disappeared (Walters 1955). It has been more frequently reported in the Mackenzie River delta region than elsewhere in the Canadian Arctic, ranging upriver to about the Arctic Red River (Wynne-Edwards 1952). This same form ranges west into Eurasian waters, being displaced in the region of the White Sea by the European smelt, usually called *O. eperlanus*, which ranges south along the European coastal regions to the British Isles and France.

Biology The smelt is an anadromous species like the alewife, and, in the spring, leaves the sea or large lake and ascends freshwater streams to spawn. Living in the sea and entering fresh water to spawn seems to have been the usual and most successful way of life for smelt, but, like many anadromous fishes, it can live successfully in fresh water throughout its life.

The life history pattern is much the same for both marine and freshwater populations.

Ripe smelt begin to ascend streams in the spring not long after the ice is out, usually in March, April, or May, the precise time depending on locality and weather. McKenzie (1964) classified streams of the Miramichi River system, N.B., as early, middle, or late, depending on when the spawning run occurred, noting that, from year to year, the time of spawning was quite regular for each stream. Early spawners usually left the stream before water temperatures reached 50° F (10° C), late spawners usually left before temperatures reached 59° F (15° C).

In the Great Lakes region, spawning usually occurs in streams but not invariably so. If exceedingly stormy weather prevails during the spawning period, there is good evidence to indicate that smelt may spawn off-shore on gravel shoals. Indeed shore-spawning may be as successful as stream-spawning and of greater importance to the survival of the species than previously realized (Rupp 1965). Streams in the Great Lakes watershed do not seem to be as readily classified as those in New Brunswick but, in general, spawning runs do not occur until the water temperature rises to at least 48° F (8.9° C) in the earliest streams, or to continue after 65° F (18.3° C) in later streams. Spawning may last for up to 3 weeks, but the peak seldom lasts more than a week. Both Bailey (1964) and McKenzie observed that the lengths of fish of both sexes decreased as the spawning season progressed. In all regions, spawning takes place mainly at night, the spawners dropping downstream to the lake by day. Two or more tuberculated males maintain positions against a female in swift water, the eggs are released in clusters and presumably the milt is released simultaneously. Langlois (1935) has given one of the few written accounts of smelt spawning behaviour and he mentioned that he never observed milt being released. The eggs become adhesive shortly after extrusion (McKenzie said 15–20 seconds) and quickly become attached to bottom gravel. The outer coat of the egg adheres to an object. The coating is pulled off the egg by the current except at the one point of attachment, allowing the egg to sway in the water, balloonlike, attached to the substrate by the holdfast or stalk formed from the coat.

The total number of eggs extruded depends upon the size of the female, larger females having more eggs. The following figures on egg number are taken from McKenzie for the Miramichi, from Baldwin (1950) for South Bay, Lake Huron, and from Bailey for Lake Superior.

	Length of female		Egg number
	(inches)	*(mm)*	
Miramichi R.	5.0–8.2	127–209	8500–69,600
South Bay, L. Huron	5.5–7.5	140–190	9650–26,800
L. Superior	8.1	206	30,705

Bailey calculated that, on the average, Lake Superior fish contained 14,673 eggs per ounce of female. The eggs are 0.9–1.0 mm in diameter and hatch in 2–3 weeks depending on temperature. For Miramichi stocks, McKenzie gave hatching times of 29 days at 42.8°–44.6° F (6°–7° C), 25 days at 44.8°–46.4° F (7.1°–8.0° C), and 19 days at 48.2°–50.0° F (9°–10° C). The young are about 5 mm long when hatched, and drift downstream to lake or estuary. Growth is fairly rapid, depending upon the local environment. In a few months the young may measure 20–40 mm long and are exceedingly slender and nearly transparent. By August they may be 2 inches (51 mm) long and can be found close inshore along sand and gravel beaches. The embryology of the smelt was described and illustrated by Kendall (1927) but the figure used is taken from Ehrenbaum (1894) and applies to *O. eperlanus. See also* Marcotte and Tremblay (1948).

The age of smelt can be determined by examination of scales. Growth continues to be rapid. For Lake Superior stocks, Bailey noted that none were mature after one growing season, a few after two, and all were mature after three growing seasons. McKenzie noted for Miramichi stocks that 66% of spawners